An exploratory evaluation of a prototype intervention designed to develop core Executive Function skills in young adolescents in school and with a focus on the Shift component

A thesis submitted to The University of Manchester for the degree of Doctorate in Educational and Child Psychology in the School of Environment, Education and Development

2015

Susan Miranda Darby

Institute of Education
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of abbreviations</td>
<td>11</td>
</tr>
<tr>
<td>Abstract</td>
<td>12</td>
</tr>
<tr>
<td>Declaration</td>
<td>13</td>
</tr>
<tr>
<td>Copyright statement</td>
<td>13</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>14</td>
</tr>
<tr>
<td><strong>Chapter 1 Introduction</strong></td>
<td>15</td>
</tr>
<tr>
<td>1.1 Chapter outline</td>
<td>15</td>
</tr>
<tr>
<td>1.2 Brief rationale</td>
<td>15</td>
</tr>
<tr>
<td>1.3 Immediate context</td>
<td>17</td>
</tr>
<tr>
<td>1.4 Outline of remaining chapters</td>
<td>19</td>
</tr>
<tr>
<td>Chapter 2: The literature</td>
<td>19</td>
</tr>
<tr>
<td>2.1 Chapter outline and aims</td>
<td>22</td>
</tr>
<tr>
<td>2.2 The literature search</td>
<td>22</td>
</tr>
<tr>
<td>2.2.1 Search strategy</td>
<td>22</td>
</tr>
<tr>
<td>2.2.1.1 Strategy for Executive Function literature</td>
<td>22</td>
</tr>
<tr>
<td>2.2.1.2 Strategy for additional literature</td>
<td>23</td>
</tr>
<tr>
<td>2.2.2 Literature identified</td>
<td>24</td>
</tr>
<tr>
<td>2.3 The study’s pragmatic rationale</td>
<td>24</td>
</tr>
<tr>
<td>2.3.1 Conceptualisation of Executive Function</td>
<td>25</td>
</tr>
<tr>
<td>2.3.1.1 Definition</td>
<td>25</td>
</tr>
<tr>
<td>2.3.1.2 Links with other cognitive processes</td>
<td>28</td>
</tr>
<tr>
<td>2.3.2 The importance of Executive Function</td>
<td>29</td>
</tr>
<tr>
<td>2.3.3 The extent of at-risk groups</td>
<td>30</td>
</tr>
<tr>
<td>2.3.4 Existing interventions having some evidence base</td>
<td>30</td>
</tr>
<tr>
<td>2.3.5 Perception of need in the classroom</td>
<td>35</td>
</tr>
<tr>
<td>2.3.6 The knowledge gap</td>
<td>36</td>
</tr>
<tr>
<td>2.4 The theoretical background</td>
<td>37</td>
</tr>
<tr>
<td>2.4.1 Are general cognitive functions theoretically amenable to intervention?</td>
<td>38</td>
</tr>
<tr>
<td>2.4.1.1 Should neuroscience inform interventions in education?</td>
<td>38</td>
</tr>
<tr>
<td>2.4.1.2 How does EF develop and respond to the environment?</td>
<td>41</td>
</tr>
<tr>
<td>2.4.1.2.1 The development of EF and its components</td>
<td>41</td>
</tr>
</tbody>
</table>
Word Count: 57,694 including footnotes as well as figures and tables within main text
List of Figures

Figure 2.1: Miyake and Friedman’s (2012) unity and diversity model .............27
Figure 2.2: Direct and indirect EF intervention .............................................31
Figure 2.3: A proposed model of Working Memory ........................................49
Figure 2.4: A reflective multi-tiered measurement model ..............................51
Figure 2.5: Stimuli examples from a typical Shift task ...............................54
Figure 2.6: Stimuli examples from a typical Stroop task .............................55
Figure 2.7: Basic Shift-task paradigm .........................................................60
Figure 2.8: Factors and skills affecting stimulus processing ............................61
Figure 2.9: Choosing and using the right response in a Switch-task ..........63
Figure 2.10: Principles offered by social mediation and cooperative learning...65
Figure 2.11: Ecological framework for understanding effective implementation68
Figure 2.12: A diagrammatic summary of earlier findings .........................72
Figure 3.1: Research structure and method mix ...........................................82
Figure 3.2: A diagrammatic summary of the implementation .....................87
Figure 3.3: Time series data tables from student booklet ............................92
Figure 4.1: Final thematic map for first expert group .................................103
Figure 4.2: A model of EF intended to show its limited capacity ............107
Figure 4.3: Matrix of EF variation ...............................................................108
Figure 4.4: Final thematic map for second expert group ............................109
Figure 4.5: Practical suggestions for the prototype intervention ...............115
Figure 4.6: The final thematic map for the stakeholder group ...................116
Figure 4.7: Bar chart showing mean combined scaled scores before and after intervention .................................................................122
Figure 4.8: Bar chart showing mean contrast scaled scores before and after intervention ......................................................................................124
Figure 4.9: Bar charts showing changes in performance for each participant.125
Figure 4.10: Bar chart showing the mean Total Error scaled score before and after the intervention .................................................................129
Figure 4.11: Bar chart showing the change in corrected Total Error scaled scores for each participant .................................................................129
Figure 4.12: Classroom diagram .................................................................131
Figure 4.13: Final thematic map for facilitators .........................................133
Figure 4.14: Final thematic map for student participants .........................138
Figure 5.1: Copy of the proposed model of Working Memory ..................147
Figure A2.1: Miyake and Friedman’s (2012) unity and diversity model ....226
Figure A2.2: Diagram of prefrontal cortex and related structures .............229
Figure A2.3: Pictures Inhibition task using Simon Effect .............................................. 250
Figure A2.4: Contingency Card Naming Shift-task ............................................................. 251
Figure A2.5: Example of colour/shape composite Switch-task ......................................... 252
Figure A2.6: Switch-task using Stroop Effect .................................................................... 252
Figure A2.7: Principles offered by The Learning Hierarchy research ................................. 253
Figure A2.8: Principles offered by Flow ............................................................................. 254
Figure A2.9: Principles offered by comic strip conversations .......................................... 255
Figure A4.1: Examples of particular tasks .......................................................................... 311
Figure A4.2: The first four pages of the draft student booklet ........................................ 314
Figure A4.3: Examples of the tasks suggested by the pre-prototype ................................ 315
Figure A4.4: Annotated transcript from the second expert group .................................... 316
Figure A4.5: Initial thematic map from the second expert group ..................................... 317
Figure A4.6: Intermediate thematic map from the stakeholder group ............................. 318
Figure A4.7: The first four pages from the student booklet ............................................. 321
Figure A4.8: Example of card-based task including a rule card ..................................... 322
Figure A4.9: Example of sheet-based tasks ..................................................................... 323
Figure A4.10: Anonymised example of personalised feedback letter ............................. 329
Figure A4.11: Anonymised summary of results provided to school participants ............ 330
Figure A4.12: Graphs of scaled scores pre-test ................................................................. 336
Figure A4.13: Calculations for retest score corrections ..................................................... 337
Figure A4.14: Calculations for Wilcoxon matched pairs test ........................................ 340
Figure A4.15: Calculations for sample size, power and effect size .................................. 345
Figure A4.16: Mean change by initial score level ............................................................. 347
List of Tables

Table 2.1: Phenomena measured in Shift/Switch research ........................................ 56
Table 2.2: How to manipulate Shift-task difficulty ......................................................... 62
Table 2.3: Tasks retained after pilot work ...................................................................... 63
Table 2.4: Factors and characteristics that affect implementation ............................... 69
Table 3.1: Scores generated by the NEPSY-II Inhibition subtest ................................. 94
Table 4.1: Participants making most apparent progress with Naming skills ...... 126
Table 4.2: Participants making most apparent progress with Switch skills .... 126
Table 4.3: Participants making least apparent progress with Naming skills ... 127
Table 4.4: Participants making least apparent progress with Switch skills .... 128
Table 4.5: Diary observation themes ........................................................................... 141
Table A2.1: Key research papers .................................................................................. 217
Table A2.2: Results from searching Web of Science on 22/12/14 ...................... 221
Table A2.3: Results from searching TRIP on 22/12/14 ............................................. 223
Table A2.4: Results from searching ETHOS on 22/12/14 .......................................... 223
Table A2.5: Examples of studies attempting to locate EF components .............. 230
Table A2.6: Associations between EF and outcome measures ............................... 233
Table A2.7: Factors that influence the development of EF skills ......................... 236
Table A2.8: Research on interventions for general EF ............................................. 238
Table A2.9: Research exploring EF component development ............................... 245
Table A3.1: Timeline and time budget ....................................................................... 272
Table A3.2: Operational risk analysis ......................................................................... 275
Table A4.1: Main sections of notes sent before the first expert group ............... 306
Table A4.2: Revised matrix with tasks inserted ......................................................... 310
Table A4.3: The task matrix presented to the stakeholder group ....................... 312
Table A4.4: The core intervention tasks ..................................................................... 313
Table A4.5: Examples of codes per theme - from the stakeholder group ......... 319
Table A4.6: The additional notes for facilitators ......................................................... 324
Table A4.7: Raw and standardised scores for each participant ......................... 332
Table A4.8: Comparison of percentage banding with scaled scores .................. 338
Table A4.9: Contrast scaled scores for all participants ............................................. 339
List of Appendices

Appendix 1: Glossary of terms ................................................................. 210
Appendix 2.1 Information regarding the literature search .................................. 216
Appendix 2.2: A broader description of EF definitions and conceptions .......... 224
Appendix 2.3: EF links with brain anatomy and physiology .......................... 228
Appendix 2.4: Associations between EF and outcome measures .................. 233
Appendix 2.5: Factors that influence the development of EF skills .................. 236
Appendix 2.6: Research papers describing interventions for general EF ........ 238
Appendix 2.7: Examples of research exploring EF component development .... 245
Appendix 2.8: Outlines of key Switch task papers .................................. 248
Appendix 2.9: Shift task examples ........................................................... 250
Appendix 2.10: Diagrammatic summaries of additional research areas ........ 253
Appendix 3.1: Research invitations and consent forms .................................. 256
Appendix 3.2: Detailed research schedule and operational risk analysis ......... 272
Appendix 3.3: Interview and focus group schedules ................................... 276
Appendix 3.4: Prompts supplied in programme facilitator diaries ................. 278
Appendix 3.5: Ethics forms submitted and approved and research approval details ................................................................. 279
  Research risk and ethics assessment form ......................................... 279
  School of Education ethical approval application form ......................... 292
  Minor amendment to research project ............................................... 305
Appendix 4.1: Materials sent to experts before the first group interview .......... 306
Appendix 4.2: Additional materials developed for the second expert group .... 310
Appendix 4.3: Materials taken to the stakeholders’ group ......................... 312
Appendix 4.4: Example of annotated transcript ...................................... 316
Appendix 4.5: Examples of initial and intermediate thematic maps ............... 317
Appendix 4.6: Examples of excerpts for final themes/codes ....................... 319
Appendix 4.7: Samples of the prototype materials ................................... 321
Appendix 4.8: Hypothetical example of an intervention session ................. 325
Appendix 4.9: Information provided to participants after the end of the intervention ...................................................................................... 329
Appendix 4.10: Quantitative data detail ..................................................... 332
## List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>Executive Function</td>
</tr>
<tr>
<td>EP</td>
<td>Educational Psychologist</td>
</tr>
<tr>
<td>TEP</td>
<td>Trainee Educational Psychologist</td>
</tr>
<tr>
<td>PFC</td>
<td>Prefrontal cortex</td>
</tr>
<tr>
<td>SENCo</td>
<td>Special Educational Needs Coordinator</td>
</tr>
</tbody>
</table>

Please note that Appendix 1 is a glossary.
Abstract

Executive Function (EF) comprises general purpose control processes that regulate thoughts and behaviours. Underlying core skills have been identified, including Shift: the ability to move between mental states, operations, or tasks. Research implicates EF (and Shift specifically) in academic achievement and broader life functioning throughout the life span. Most attempts to develop EF skills directly have focused on memory aspects and/or younger children. Reported benefits are controversial and perhaps limited. This research tackles a particular gap: intervention with adolescent core EF skills, with a focus on Shift, in a typical educational setting.

All participant sampling was by convenience. Two experts in EF and three local stakeholders guided intervention development. 22 mainstream Year 8 students (one tutor group) trialled the resulting intervention prototype. A teaching assistant facilitated the implementation, with the form tutor present to occasionally assist.

Being an exploratory evaluation, this research used mixed methods with an emphasis on qualitative data. Semi-structured group interviews with experts and a stakeholder focus group were used during the development phase. Standardised baseline and retest data were collected up to three weeks before and four weeks after the implementation phase respectively: a half term’s trial during morning form-time. This was complemented by semi-structured feedback interviews with the participating adults and eight students.

Transcripts were analysed with Thematic Analysis and the researcher’s diary with Content Analysis. The quantitative data were summarised with descriptive statistics and additionally analysed with nonparametric inferential statistics.

The study extends available data describing the near benefits of EF intervention. It explores the likely utility of EF intervention both theoretically and from an implementation perspective.
Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

All information contained in this thesis has been anonymised to protect participant confidentiality.

Copyright statement

The author of this thesis (including any appendices and/or schedules to this thesis) owns certain copyright or related rights in it (the “Copyright”) and she has given The University of Manchester certain rights to use such Copyright, including for administrative purposes.

Copies of this thesis, either in full or in extracts and whether in hard or electronic copy, may be made only in accordance with the Copyright, Designs and Patents Act 1988 (as amended) and regulations issued under it or, where appropriate, in accordance with licensing agreements which the University has from time to time. This page must form part of any such copies made.

The ownership of certain Copyright, patents, designs, trademarks and other intellectual property (the “Intellectual Property”) and any reproductions of copyright works in the thesis, for example graphs and tables (“Reproductions”), which may be described in this thesis, may not be owned by the author and may be owned by third parties. Such Intellectual Property and Reproductions cannot and must not be made available for use without the prior written permission of the owner(s) of the relevant Intellectual Property and/or Reproductions.

Further information on the conditions under which disclosure, publication, and commercialisation of this thesis, the Copyright and any Intellectual Property and/or Reproductions described in it may take place is available in the University IP Policy (see http://documents.manchester.ac.uk/DocuInfo.aspx?DocID=487), in any relevant Thesis restriction declarations deposited in the University Library, The University Library’s regulations (see http://www.manchester.ac.uk/library.aboutus/regulations) and in The University’s policy on presentation of Theses.
Acknowledgements

To list is to omit and so I don’t, well not exactly. Some people who helped with the creation of this thesis know that they did; many others do not.

If you at any stage:
- took part in formative discussion
- laminated, chopped and chomped
- were in a classroom ‘having a go’
- read draft offerings
- typed when I couldn’t
- cooked when I wouldn’t
- phoned/eMailed/Facebooked to ask how it was all going
- gave temporary permission for me to be a lousy parent, partner, friend, colleague and member of the human race
- said it would all be worth it in the end
then you helped to produce what follows. I hope it does you all justice. Thank you.
Chapter 1  Introduction

1.1 Chapter outline
This chapter firstly provides a brief literature-based rationale for the research and then the immediate contextual rationale with associated information. Then it outlines the structure and content of the remaining chapters.

1.2 Brief rationale
Executive Function (EF) refers to a group of cognitive control processes whose use requires effort and that are needed when instinct and intuition are insufficient (Diamond, 2013). As such it constitutes a set of general purpose control processes that regulate one's thoughts and behaviours (Miyake & Friedman, 2012). A number of authors conceptualise EF into constituent processes and components (Anderson, Northam, Hendy & Wrennall, 2002; Dawson & Guare, 2010; Lezak, Howieson, & Loring, 2004). The model proposed by Miyake and colleagues (Miyake et al., 2000) has reached particular prominence and has been used to structure ensuing reviews and research (Best, Miller, & Jones, 2009; Buss & Spencer, 2014; Diamond, 2013). This model consists of three components, alongside common processing:
- Inhibition is the ability to suppress a dominant or automatic or prepotent response.
- Updating of Working Memory is the ability to maintain and manipulate information over brief periods of time.
- Shifting is the ability to shift between mental states, operations, or tasks (Miyake et al., 2000).

Research interest in EF has proliferated during recent years as its importance in facilitating academic achievement and day-to-day self-regulation has become recognised (Buss & Spencer, 2014; Garon, Bryson, & Smith, 2008; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012). Lagging somewhat, but nevertheless beginning to accumulate, is evidence-based opinion that effective EF interventions can be developed and implemented (Diamond, 2013; Diamond & Lee, 2013; Greenberg & Rhoades, 2008). To date, EF interventions have largely focussed on younger children’s EF, either as a whole or by explicitly boosting all three components (Blair & Diamond, 2008; Röthlisberger et al., 2012), since EF develops rapidly during the early years (Best et al., 2009; Best & Miller, 2010).
There are now calls to target EF in adolescence, as the supporting brain substrates demonstrate continual plasticity and a prolonged period of development (Greenberg & Rhoades, 2008). To date, the majority of direct research effort in older school-aged children has concentrated on the component Working Memory (Diamond, 2012; Holmes & Gathercole, 2013). However, laboratory work suggests that Shift could be a useful focus (Diamond, 2012; Karbach & Kray, 2009), whilst Inhibition seems to have a mediating role in some indirect interventions (Riggs, Greenberg, Kusché, & Pentz, 2006). Clearly there is room for further development work.

Explicitly then, beyond Working Memory programmes, there are few interventions available for schools to use with their students with the specific aim of enhancing EF (McClosky, Perkins & Van Divner, 2009). Those that do exist (Dawson & Guare, 2009, 2010, 2012; Guare, Dawson, & Guare, 2013) seem to have a limited evidence base and look to accommodate need at a group level. Where they aim to boost underlying skills, intensive individual support is suggested.

Therefore, an effective intervention, developed with some rigor to boost either EF as a whole or some component parts of it and targeting adolescents, would be of potential significance to all secondary settings. This would pertain, regardless of their specific context and population, because of the demonstrated links with academic achievement and emotional and behavioural self-regulation.

The development work needed to underpin such an intervention constitutes substantial applied research that is ambitious not least because of the paradigm shifts required to link between the various relevant discourses (Howard-Jones, 2008, 2014). This researcher believes that Educational Psychologists (EPs) are relatively well placed to conduct such research because they have the academic background to allow engagement with a broad literature base, they are expected to work using evidence-based practice and they experience day-to-day how schools attempt to meet the needs of their students.

Looking at the legislative context in which EPs are currently working, there is a preoccupation certainly within this researcher’s local authority to build the systems and skills to ensure compliance with the recent Children and Families Act (HMG, 2014). Within this legislation there is an emphasis on ensuring preparation for adulthood, exemplified by, “clear outcomes .. that are ambitious and stretching and
which will prepare young people for adulthood” (DfE & DoH, 2014, pg 114). The legislation places EPs in a central role in suggesting suitable outcomes and associated strategies (DfE & DoH, 2014). Given the important associations of EF with outcomes throughout the life span (Diamond, 2013), EF intervention research conducted by EPs sits well alongside this current legislative agenda.

Addressing a small part of the combined research gap, this work contributes some early steps towards providing an effective EF intervention that has a particular focus on Shift and that could be delivered to a group of adolescents by the staff that would typically be tasked. It builds on earlier pilot work (Darby, 2013 a, b) that explored first stages of feasibility, gauging secondary school staff perceptions of need and exploring possible intervention tasks for a secondary setting. At that time, the author had been unable to locate literature that directly addressed either of these issues, although it was possible to use precedence set for direct EF intervention with pre-school children (Röthlisberger et al., 2012) to endorse a harvesting of tasks from the literature.

This study attempts to move Shift intervention beyond the laboratory (Karbach & Kray, 2009), by developing a programme with a sound theoretical basis that can be implemented in a mainstream secondary setting and that can also produce some tentative positive results.

### 1.3 Immediate context

The researcher is a trainee educational psychologist (TEP) at the University of Manchester. A mixture of experiences influenced her choice of research topic and the nature of the study. She had recognised that the overlapping fields of neuroscience and EF have accumulated an abundance of research in recent years that any TEP should make time to engage with. Teaching experience had suggested that some pupils are more able than others to marshal their intellect towards fruitful learning. As a TEP, casework and previous research (Darby, 2013a) had shown how differently primary and secondary schools seem able to support EF day-to-day and to implement interventions. Lastly, this researcher had some experience of product/programme evaluation, including within education.

The earlier pilot carried out as a TEP (Darby, 2013 a) suggested that school staff are able to identify pupils who demonstrate poorer EF skills and they currently accommodate them through classroom management and lesson differentiation.
Staff recognised potential benefits of boosting EF both for the school in terms of improving results and for society by having better functioning adults, but felt that any exploratory attempts would have to minimise risk to curriculum delivery through exempting older pupils and core subject time. This work also suggested that pupils in early adolescence (Year 7) would be prepared to engage with tasks directly focussing on Shift and it gave pointers for characteristics that would be important to design into an intervention (Darby, 2013 b). At this time the Shift tasks were simply a collection of likely suitable activities.

The current study was hosted by a mainstream secondary school within the local authority providing the main fieldwork placement for this researcher. The local authority is small, with a population of approximately 126,000 (ONS, 2013) and school population of approximately 19,000. It is within the 10% most deprived local authorities in England (DfCLG, 2010) as measured by the Index of Multiple Deprivation and almost 30% of the children in school claim free school meals (DfE, 2014).

Looking more specifically at the school, in 2013 it had approximately 1100 pupils on role (just within the largest 40% of schools nationally), the proportion of pupils eligible for free school meals was in the highest 40% and it achieved almost 70% 5A*-C at GCSE (in the 40% highest performing schools in its group of similar schools) (Ofsted, 2014). Hence, the school would seem to be performing well relative to other similar schools nationally.

The school achieved Outstanding in its latest Ofsted inspection in 2010 (Ofsted, 2010). It became a Designated National Teaching School in 2012, was converted to an academy in September 2012 and it opened a 6th form in September 2014. At the time of this study, the school was typical within the local authority in terms of its academy status and becoming an 11-18 school.

Overall, the school would appear to be representative of effective mainstream secondary education and the study results should be widely applicable. Equally, it is hypothesised that successful EF intervention could positively influence the school population through improving flexible self-regulation and attention/concentration skills and thereby behaviour and academic performance.

\[1\] Exact figures are not given in this and the following two paragraphs, to support participant anonymity.
A Year 8 tutor group took part in a half-term’s trial. It was largely managed by a teaching assistant, as would typically be the case for interventions in that school. When the study was planned the then Principal Educational Psychologist had a particular interest in neuroscience. The Educational Psychology Service as a whole promotes research through hosting conferences, currently including the annual North West Continuing Professional Development Conference for Educational Psychologists.

1.4 Outline of remaining chapters

Each chapter starts with a short section outlining the contents and aims.

Chapter 2: The literature

Chapter two contains a brief description of the scope and search parameters of the literature trawl and then three main sections (2.3, 2.4 and 2.5).

Section 2.3 provides an expanded pragmatic research rationale. After choosing a specific EF conception (Miyake et al, 2000), it indicates the importance of EF throughout the life span and those children who stand to benefit most from EF support or intervention. Then it describes existing EF interventions, before grounding the rationale further by looking at perception of need as reported by teaching staff. Section 2.3 finishes by again summarising the knowledge gap being addressed. The research questions are outlined later, at the end of the chapter for ease of location.

Section 2.4 provides a theoretical research rationale and through this hopefully also a sense of the earlier stages of the research journey. Towards the end it also visits more disparate literature areas that previous work had indicated might provide useful design suggestions.

In more detail, the theoretical rationale engages with the debate regarding the application of neuroscience to education and looks at the logical possibility of EF intervention in adolescence by exploring EF development and associated brain change, as well as the concept of heritability. It attempts to link EF with other cognitive models, to visit criticism of the chosen EF model and to investigate the Shift task paradigm in some detail. Pulling these strands together it creates a theoretical rationale that incorporates mechanisms for intervention benefit.
The more disparate literature areas (Learning Hierarchy, social mediation, Flow and comic strip conversations) are visited briefly to extract design suggestions.

Section 2.5 places the study within evaluation and implementation research and provides issues for consideration during and after the implementation phase.

Chapter two concludes with a literature summary, an outline of the research aims and a statement of the research questions. To reiterate, the study aimed to develop an EF intervention for adolescents that had a sound theoretical basis, that focussed on Shift and that could be implemented in a mainstream secondary setting, potentially also producing some positive results.

**Chapter 3: The methodology**

This chapter describes the methodology underpinning the research: a quasi-mixed methods early stage evaluation of an EF intervention focussing on Shift in adolescence. It addresses the ideological positions adopted by the researcher that have necessarily informed the research design and its associated methods of gathering and analysing data. Having described these aspects of the research, this chapter then provides critique, including ideological, methodological and ethical considerations.

**Chapter 4: Results**

The chapter contains three main sections.

Section 4.2 is an outline of the research’s theoretical development work and a description of its output: a task matrix that forms the basis of the intervention package, i.e. a pre-prototype. This work was informed by the findings of two group interviews with EF experts.

Section 4.3 is a description of how the pre-prototype was translated into the prototype intervention package used in the evaluation implementation. This work was influenced by the hints collated from experts, from the additional literature areas and a focus group of local stakeholders.

Section 4.4 describes what happened during the implementation, both in terms of quantifiable skill change and qualitative perceptions of how usable the intervention had been and what useful benefits it could promote. Skills were measured with a
standardised test. Perceptions were provided through feedback interviews with staff and students involved and ideas captured in the researcher’s diary.

**Chapter 5: Discussion and conclusions**

This chapter summarises and critiques the main findings within a structure created by considering each research question in turn. Then the study as a whole is discussed and some final conclusions are drawn.
Chapter 2  The literature

2.1 Chapter outline and aims
This chapter firstly describes how the existing literature was interrogated including the search, filter and time parameters that were imposed.

It then aims to provide:
- an expanded pragmatic rationale for the study
- the background needed to theoretically inform and permit the development of a Shift intervention, both in the immediate area of EF and Shift, as well as some more disparate but potentially relevant areas and
- an account of implementation and evaluation research that locates this study towards the beginning of the development process and suggests suitable evaluation methodology.

The chapter then summarises these three strands and reiterates the research gap addressed. Finally, it considers why EPs (qualified or in training) are well-placed to work in this area and it concludes with the research questions being asked.

2.2 The literature search

2.2.1 Search strategy

2.2.1.1 Strategy for Executive Function literature

At the beginning of the pilot work, five questions were asked of the literature. The aim was to gain an understanding of EF and to develop a pragmatic rationale through identification of a research gap. The questions were:

1. Is adolescence a suitable time to boost EF?  (Implicitly this addresses EF development.)
2. Should an intervention target EF as a whole or a constituent part?  (Implicitly this addresses the meaning of EF to neuropsychologists in terms of cognitive models and links with biological substrates.)
3. What interventions currently exist: what and who do they target and are they successful?
4. Why is EF (and Shift) important in schools?
5. Is EF recognised in schools as relevant and important?  (Implicitly this addresses the meaning of EF to educationalists in terms of what they see in the classroom and the extent of their formal knowledge.)
The questions were answered through searching the PsychInfo and ERIC academic databases in April and May 2013 with combinations of the following keyword search terms: ‘Executive Function*’, ‘Set shift’, ‘Response shift’, ‘Shift’, ‘Switch’, ‘Intervention’, ‘Development’, ‘Component*’, ‘Achievement’ and ‘Teacher’. From then until March 2015, weekly updates with ‘Executive Function’ as a keyword were received from Zetoc and Web of Knowledge.

Throughout, papers were accepted or rejected according to the following criteria:
- appearance in a peer reviewed journal
- relevance, initially to the five search questions but later to this proposed study and its envisaged literature review
- availability in English
- recency and specifically to have been published within the last 15 years and
- full text available electronically through the University’s journal access arrangements.

In addition, some literature was harvested from University reading lists and papers already acquired. Since it was harvested for particular relevance, this literature was not filtered in the same way and some is Grey literature from books and government guidelines.

The volume of new literature to sift has been considerable; EF has recently attracted great research interest, reflected in the rapidly increasing volume of publications (Garon, Bryson, & Smith, 2008; Willoughby, Holochwost, Blanton, & Blair, 2014).

2.2.1.2 Strategy for additional literature

Following the earlier research (Darby, 2013a,b), a wider knowledge base was felt to be necessary and so a number of additional literature searches were conducted. Specifically, the following keyword combinations were used to search the PsychInfo and ERIC academic databases in September 2013: ‘social* + mediat* + learning’, ‘cooperative + learning’, ‘paired + learning’, ‘instructional + hierarchy’, ‘implementation + school + intervention’, ‘neuroscience + education + school-based intervention’, ‘working memory + education + intervention’, ‘comic + strip + conversation*’, ‘distributed + practice’, ‘interleaved + learning’.

Corresponding Zetoc updates were also set up and monitored until November 2014.
The same criteria for inclusion were used as above, except that older papers were tolerated where not many were generated.

Further databases were searched in December 2014 using ‘Executive Function*’ as a within-title search term to ensure useful literature from key additional areas had not been omitted. Again, the criteria for inclusion were as above, but because of the later search date, retained literature also had to add to the picture in a substantive way, as judged by this author:
- TRIP and Web of Science (that includes PubMed) to search neuropsychiatry literature and
- The British Library’s ETHOS database to search theses. The search was confined to theses available through ETHOS or the relevant institutions.

2.2.2 Literature identified
Over time the strategy for identifying Executive Function research generated a large number of papers and a second filtering rationale was applied. Some papers were used for brief contributions to help establish an overview, for example regarding the state of intervention research. A relative few became key papers in one or more areas and Table A2.1 in Appendix 2.1 indicates those so privileged.

The later additional database searches for EF literature identified papers that could have provided further brief contributions in line with the general overview, but none that reported substantive different findings that required insertion. This judgement can be verified, see Tables A2.2, A2.3 and A2.4 in Appendix 2.1.

For the papers identified to inform a wider knowledge base (including implementation research, social mediation and Flow), no further filtering was required. The numbers were manageable and the content was more directly relevant, perhaps due the later search date and hence the study then being specified in more detail.

Having described how relevant literature was identified, this chapter now uses the next three sections to review it, starting with the study’s pragmatic rationale.

2.3 The study’s pragmatic rationale
After a brief exploration of EF conceptualisation that also considers relationships with other cognitive functions, this section then outlines EF’s wide-ranging influence, the extent of at-risk groups and the nature of existing interventions having some evidence base. Key studies, i.e. those most closely related to this
research are reported, including the researcher’s pilot work (Darby, 2013a,b). The latter is referred to as a marker of progress in the current research journey and as an anchor for the study rationale in UK secondary education. At this point the particular knowledge gap will be pinpointed, although the research questions will be given at the end of the chapter, as fits convention and hence for ease of location.

2.3.1 Conceptualisation of Executive Function

2.3.1.1 Definition

Executive function (EF) as a whole can be defined as “a set of general purpose control processes that regulate one’s thoughts and behaviours” (Miyake & Friedman, 2012, pg. 8) or as the “superordinate, managerial capacity for directing more modular activities, including language, memory, motor skills and perception in the service of setting, managing and attaining goals” (Levin & Hanten, 2005, pg. 79). It is broadly implicated in the control of both cognitive processing and affective self-regulation¹ (Best, Miller, & Jones, 2009; Friese, Binder, Luechinger, & Boesiger, 2013; Martel, Roberts, & Gremillion, 2013) and it underlies “the ability to adjust behaviour rapidly and flexibly to the varying demands of the environment” (Huizinga & van der Molen, 2007, pg. 193).

The term EF has arisen from observations that adults with damage to the prefrontal cortex might have intact sensory processing, speech, intelligence and/or movement, but would tend to have difficulty with planning, organising, controlling/sustaining and adapting their thoughts and behaviours (Best et al., 2009; Gilbert & Burgess, 2008; Shallice and Burgess, 1991).

Since these observations were first made, there have been attempts to detail EF more exactly by describing its constituent parts (Best et al., 2009), in terms of both the cognitive processes and the supporting brain anatomy and physiology. This work firmly focusses on cognition. The adopted model (Miyake et al., 2000) is described below. There are others and a flavour of these is given in Appendix 2.2. Nevertheless this work is informed by and arguably should not run counter to

¹ Since affect can modify performance on traditional cognitive tasks (Pnevmatikos & Trikkaliotis, 2013; Yang & Yang, 2014), this researcher has chosen to adopt these broad EF definitions, in line with some authors (Brocki & Bohlin, 2004; Levin & Hanten, 2005), but recognising that others prefer to distinguish between cognitive processing (cool EF) and affective self-regulation (hot EF) (Hongwanishkul, Happaney, Lee & Zelazo, 2005; Prencipe et al., 2011; Schoemaker et al., 2013).
neuroscience findings and a brief description of the anatomy and physiology of EF can be found in Appendix 2.3. It suffices here to say that EF is primarily associated with pre-frontal cortex (Powell & Voeller, 2004). This part of the brain receives pre-processed sensory, emotional and autonomic information and has access to memory (Powell and Voeller, 2004) and as such is well placed to house and control interactions between higher and lower level processes (Gilbert & Burgess, 1990).

Looking now at the **EF model adopted for this study (Miyake et al., 2000)**, its intended aim had been to capture fundamental underlying processes and core components. Using confirmatory factor analysis, Miyake and her colleagues analysed adult performance on experimental EF tasks. As well as identifying some common processing, they found three distinguishable components:

- Inhibition that is the ability to suppress a dominant or automatic or prepotent response.
- Updating of Working Memory that is the ability to maintain and manipulate information over brief periods of time.
- Shifting that is the ability to shift between mental states, operations, or tasks (Miyake et al., 2000).

The three component model has since been revisited (Miyake & Friedman, 2012) and a modified version proposed where common EF is conceived to be the ability to maintain goals and related information so as to effectively direct lower-level processing, see Figure 2.1. Inhibition as a separate component has been discarded because it correlates almost perfectly with common EF.

Within both models, EF is seen to comprise common process (Unity) and specific components (Diversity). This idea seems to acknowledge the broad regulation and monitoring function\(^2\) of EF as well as core underlying skills.

\(^2\) Arguably this broad monitoring is synonymous with metacognition: the skill and knowledge required for higher level regulation of and control over one’s learning activities (Van der Stel & Veenman, 2008). There is a large discourse around metacognition that is not addressed here. The foci of this study were the specific lower level underlying core EF skills (Miyake et al., 2000).
Adoption of the earlier model (Miyake et al., 2000) has been a largely pragmatic decision. Firstly, it provides the basis for discourse in much of the relevant research3 (Best et al., 2009; Best & Miller, 2010; Levin & Hanten, 2005; Willoughby et al., 2014). Secondly, it is an accepted model of adult functioning against which all child and adolescent behaviour can and will be compared (Garon et al., 2008). Indeed, Miyake and Friedman’s (2012) newer model could arguably be an artefact of their participants’ age, 16 to 17 year olds, as opposed to the young adults involved earlier (Miyake et al., 2000). Thirdly, the Inhibition component appears to have explanatory power in social skills interventions (Riggs, Greenberg, Kusché, & Pentz, 2006) and finally there are tasks available that are suggested and commonly used to capture the three core component skills (Miyake et al., 2000).

Exactly how EF should be conceptualised has yet to be resolved (Bogg & Roberts, 2013; Hall & Fong, 2013; Miyake & Friedman, 2012). Koziol (2014) likens the issue to “trying to nail Jell-o to a wall” (Koziol, 2014, pg.161). This issue will be revisited in the theoretical background of Section 2.4.

---

3 There are exceptions, for example Burnett, Scratch & Anderson (2013) use Anderson et al.’s (2002) EF conceptualisation.
2.3.1.2 Links with other cognitive processes

Having chosen the model (Miyake et al., 2000) to work with, it is useful to consider briefly how its components relate to other cognitive processes. It becomes clear that EF could equally be described in attentional terms\(^4\) (Garon et al., 2008).

**Inhibition** and directed or selective attention are arguably two sides of the same coin (Ikeda, Okuzumi, & Kokubun, 2013). The ability to inhibit attention to distractors including within the target stimulus (and so resist the temptation to react impulsively) allows selective/focused and sustained attention (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2013; Hu et al., 2013; Rueda, Checa, & Mary, 2010).

**Shift**, or cognitive flexibility, appears to relate particularly to attentional shift (Anderson et al. 2002; Lahat et al., 2012; Lan, Legare, Cameron, Li, & Morrison, 2011).

**Updating** is used interchangeably with Working Memory in a number of papers (e.g. Huizinga & van der Molen, 2007; Neuenschwander, Röthlisberger, Cimeli, & Roebers, 2012). It also involves cognitive inhibition of extraneous thought intrusions (Diamond, 2013).

EF also has a relationship with **intelligence**. In late adolescence it is an imperfect but positive correlation\(^5\) (Friedman et al., 2008). This is perhaps inevitable given that IQ composites typically involve measures of Working Memory. Indeed, more specifically, Friedman and her colleagues (2006, 2008) found IQ to be highly correlated to the Updating component of EF, but not to Inhibition or Shift. Similar patterns of association have been found in earlier adolescence (Duan, Wei, Wang, & Shi, 2010), whilst for younger children the evidence is more mixed (Arffa, 2007; Brydges, Reid, Fox, & Anderson, 2012; Shahabi, Abad, & Colom, 2014).

Overall then, EF seems to be intimately bound up with attention and there seems to be an association between IQ and EF, particularly with the Updating component of older children.

---

\(^4\) See glossary.

\(^5\) Using the Wechsler Adult Intelligence Scale (WAIS).
2.3.2 The importance of Executive Function

"EFs are important to study because they are a core component of self-control or self-regulation ability (or ‘willpower’), which has been shown to have broad and significant implications for everyday lives" (Miyake and Friedman, 2012, pg. 8).

Evidence of these implications comes primarily from studies that show associations between EF and various outcome measures, such as social competence in young children (Alduncin, Huffman, Feldman, & Loe, 2014), eating behaviours in adults (Hall & Fong, 2013), adolescent reasoning skills (Richland & Burchinal, 2013) and children’s academic performance (Neuenschwander et al., 2012). It is clear that impairment of EF as a whole has important day-to-day consequences across the life span. More detail can be found in Table A2.6, in Appendix 2.4.

To a more limited extent, each of the EF core components also has demonstrated relationships with important outcomes. The following select examples are for children and young people.

**Inhibition** skills are negatively related to disruptive behaviours in adolescents (Holler & Kavanaugh, 2013) and positively related to mathematics achievement in children aged 9 to 11 years (Oberle & Schonert-Reichl, 2013) and English, mathematics and science performance for 11 to 12 year olds (Clair-Thompson & Gathercole, 2006).

**Working Memory** skills are positively related to attainments in mathematics and English for 11 to 12 year olds (Clair-Thompson & Gathercole, 2006) and negatively related to the extent of social difficulty experienced by adolescents (aged 11 to 17) considered to have ADHD (Tseng & Gau, 2013).

**Shift** skills are positively related to mathematics and reading skill (Yeniad, Malda, Mesman, Ijzendoorn, & Pieper, 2013), reading and non-verbal reasoning skills in 9 to 12 year olds (Sluis, Jong, & Leij, 2007) and school grades for young adolescents with ADHD (Langberg, Dvorsky, & Evans, 2013).

Any boosting of EF skill (general or component) would seem theoretically at least to have the potential to produce wide-ranging benefits.
2.3.3 The extent of at-risk groups

Many and varying particular groups of children are more at risk of having poor EF, including those with diagnosed Autism, ADHD and/or learning difficulty, those born early or who acquire brain injury and those who suffer early adversity. Particular research examples can be found in Table A2.7, in Appendix 2.5.

It is this susceptibility to a variety of negative (and positive) influences, along with the predictive potential for many important outcomes, that seems to have stimulated the recent increase in research interest (Willoughby et al., 2014). Some positive influences are explored in the next section.

2.3.4 Existing interventions having some evidence base

There is a viewpoint that interventions are relatively scarce (McCloskey, Perkins & Van Divner, 2009; Meltzer, 2007), although later work concludes that positive evidence is building (Bryck & Fisher, 2011; Diamond, 2012, 2013; Kray & Ferdinand, 2013). The temporal proximity of these differing viewpoints is perhaps indicative of the embryonic but fast moving state of EF intervention research.

To gain an overview of intervention literature, it has been useful to classify interventions:
- as direct or indirect (see Figure 2.2 below)
- as targeting general EF or specific aspects
- by participant age, young children (up to about 6 years), pre-adolescents (about 6 to 10 years), adolescents, adults and older adults and
- by setting, laboratory or real-life.

Clearly, ideal comparison research would directly target the Shift component in adolescence, in a school setting. This researcher has not located any such work. Before the nearest hits are described, the wider field of EF intervention is briefly visited.

For children, it is the younger age groups that have received the main research attention (Röthlisberger et al., 2012). Exercise and computer training feature as intervention tools for EF as a whole, alongside schooling and parenting approaches. Particular research examples can be found in Table A2.8, in Appendix 2.6. Recent reviews have concluded that the strongest accumulated evidence is for martial arts and specific school curricular add-ons, but also that it can be difficult to pin point exact mechanisms for EF benefit and that typically
these programmes are intensive, long-lasting and costly (Bryck & Fisher, 2011; Diamond, 2013).

**Figure 2.2: Direct and indirect EF intervention (Diamond, 2012, pg. 339)**

Looking at specific components of EF, some indirect effects have been documented. Young adults who were more regularly physically active showed improvements on complex Shift tasks (Kamijo & Takeda, 2010). Also, children on the PATHS programme demonstrated increased Inhibition skills which, as a mediating variable, accounted for the successful final outcome of improved behaviour (Riggs et al., 2006). The Riggs et al. (2006) study is an important early example of improved ‘cool’ cognitive processing appearing to create affect-laden behavioural outcomes and so it supports the choice of a broad EF definition.

Turning finally now to direct intervention with specific skills, Bryck and Fisher (2011) suggest that laboratory-based training is effective in producing near transfer and hence some proof-of-concept. However, in the context of EF research any ‘broader transfer’ does not usually include real-world benefits, but instead generalisation to tasks requiring different EF skills or at best occasionally

---

6 This refers to generalisation to new tasks using the same EF skills.
also to particular skill sets such as reading or mathematics. Nevertheless, they and others conclude that the limited benefits to date are enough to warrant further research (Jak, Seelye, & Jurick, 2013) but this must attempt to understand the conditions promoting skill transfer (Kray & Ferdinand, 2013).

More specifically, Diamond (2012, 2013) concludes that\(^7\) Inhibition has yet to be amenable to specific targeted intervention\(^8\). Working Memory can be improved, the CogMed computerised training programme\(^9\) producing the strongest evidence so far. Lastly, Shift appears to be specifically trainable (Diamond, 2012, 2013), again using computer-based training (Karbach & Kray, 2009). Karbach and Kray (2009) is the first of the nearest hit studies.

**Karbach and Kray (2009)** trained the Shift skill of university volunteers in a laboratory setting using computer generated stimuli. There were three age groups, each with 56 people: 8 to 10 years, 18 to 26 years and 62 to 76 years. The Shift tasks involved simple cued classification (fruit or vegetable, large or small). Training was over four, weekly, one hour sessions. Using the same tasks as a pre- and post-test (the latter about one week after the final training session), the researchers’ found that the children showed greater training benefits than adults.

Using neuropsychological measures of Working Memory, Inhibition and fluid IQ, as well as further similar Shift tasks, Karbach and Kray (2009) found that skill transfer to similar Shift tasks was significant and most pronounced in children and older adults, whilst transfer to other executive functions was also significant but similar for all age groups. Contrary to expectation, children who had been trained using a greater variety of tasks seemed to have progressed less.

\(^7\) Diamond (2012) also extracts useful intervention principles:
- those who need most benefit most
- transfer effects are narrow for direct training
- tasks must challenge
- repeated practice is crucial, although evidence around specific dosage is mixed
- the exact nature of training matters
- effects show more if measures are demanding.

\(^8\) There is limited contrary evidence for six year olds in school and for adults trained in a laboratory (Benikos, Johnstone, & Roodeyns, 2013; Röthlisberger et al., 2012).

\(^9\) Most other evidence also relates to computer-based training programmes (Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; Van der Molen, Van Luit, Van der Molen, Klugkist, & Jongmans, 2010). Skelton (2012) is an exception.
Also focussing on Shift, Zinke et al.’s (2012) study involved 80 young adolescent participants recruited through schools and youth clubs. Again, the computer generated Shift tasks involved simple classification (car or plane, one or two), but participants needed to remember to Switch task every two items. If they lost their place they started the trial block again. Training involved three sessions, each 20 to 25 minutes, during a three week period. Using two Shift task measures, one structurally similar to training materials and one involving randomly mixed simple numeric judgements, the researchers found that reaction time Switch costs reduced, this suggesting that Shift skills had improved. Additionally, preceding the cognitive training with moderate exercise did not change its effectiveness (Zinke et al., 2012).

Otherwise the results were modest: improvements in reaction times for a Working Memory task and in the mixing cost of the similar Shift task (Zinke et al., 2012). These findings were probably explained by the lack of cues in training and hence an improved ability to hold and track two rules in mind. The authors suggest that the research produced mainly only nearest effects because the training was so limited. This author is inclined to agree: the study was extensive in measures and participants and yet involved relatively little training time, so evaluating potential training effectiveness is difficult.

Although these two studies clearly have their place as initial pieces of work, they have limitations regarding real life learning: the settings were artificial and the domains of skill transfer reported were limited and examined only a short time after training. Yet to criticise Karbach and Kray’s (2009) study particularly on this basis may not be valid. Viewed through the lens of implementation research, it constitutes a quality efficacy trial and was rightly highly controlled (Greenberg, Domitrovich, Graczyk & Zins, 2005). It provides early evidence of the kinds of tasks that could form the basis of direct intervention.

Looking at other specific EF interventions, another ‘close hit’ study used Early Years educational settings (five and six year olds), with delivery mainly by school staff (Röthlisberger et al., 2012). The authors targeted all three specific core components, using small group work carried out in 30 daily sessions of about 30 minutes each over a six-week period. Within each session there was one group

---

10 See glossary and Table 2.1.
task, one paired task and one individual task. All 19 tasks were based on well-established EF measures, such as dimension card sorting, Stroop and Trailmaking\textsuperscript{11}. At least five primarily addressed each of the three components, Updating, Shifting and Inhibition, although the authors acknowledge the impurity problem, that tasks overlap in their skill requirements. When a new task was introduced, children practised it before the difficulty level was increased. Training books with stickers were issued to maintain motivation and to document progress.

Using separate tests for each EF component and that had not been part of the training, the researchers found that for the five year olds, Working Memory and cognitive flexibility had improved, whilst for the six year olds their interference control had been enhanced. Röthlisberger et al. (2012) reported that the moderate effect sizes were comparable to programmes delivered to individuals and suggested that their work begins to prove that all three components can be enhanced in naturalistic settings.

As with the laboratory-based studies (Karbach and Kray, 2009; Zinke et al., 2012), limits on interpretation are imposed by the measures used: they demonstrate short-term gain and within the skill sets targeted. As a near hit for this study, there is an issue about generalising findings from young children to others at a different stage of development.

**Summarising the gist of intervention research to date**, it seems that it may be possible to intentionally boost EF as a whole and specifically some of its components, including Shift. However, research that attempts specific component intervention outside of the laboratory is in the earliest of stages. Providing everyday benefit has yet to be realised for most direct interventions, but this possibility should not be ruled out without further research effort (Bryck & Fisher, 2011).

Arguably, the literature considered thus far constitutes a typical pragmatic rationale used to introduce intervention research papers. This researcher has felt additionally obliged to ascertain perceived need in the classroom by those who might be expected to deliver an intervention and to understand more about the nature of EF including whether an intervention is theoretically possible.

\textsuperscript{11} See glossary.
The first of these is now explored, whilst the second constitutes Section 2.4.

### 2.3.5 Perception of need in the classroom

Until recently, teachers tended to be mentioned in EF research only in passing. They were the educationalists who responded to ratings scales providing data regarding their pupils (e.g. Peters et al. 2012) or who could feed back about an intervention (Röthlisberger et al., 2012).

Now this researcher is aware of three pieces of relevant work and they draw mutually consistent conclusions (Darby, 2013a; Hedges, 2010; Gilmore & Cragg, 2014). Previously, this researcher found that nine teachers and teaching assistants were able to identify pupils who demonstrate poorer EF skills, although they would not have used the term Executive Function. They reported them as lacking concentration, needing chunked tasks, distracting others, not coping well with change and lacking emotional control, these observations fitting well with research suggestions (Powell & Voeller, 2004). Currently these members of staff support and accommodate such pupils through classroom management (such as seating plans) and lesson differentiation (Darby, 2013a). They recognised some potential benefits of boosting EF both for their school in terms of improving results and for society through having better functioning adults (Darby, 2013a). However, they felt that any exploratory attempts would have to minimise risk to curriculum delivery through exempting older pupils and core subject time (Darby, 2013a).

Gilmore and Cragg (2014) accessed many more participants (96) through an online survey of teachers in varied settings: Early Years through to secondary. They again found that teachers were aware of EF skills, but would not have named them as such. Their awareness was gained through classroom experience rather than training; hence more experienced teachers had greater accumulated (albeit layman’s) understanding. Members of school staff in Hedges’ (2010) study were initially in a similar position and they valued the additional understanding gained through training on EF.

From the limited research available, it seems then that teachers perceive a need to work with EF, but that exploratory interventions would need to respect school pressures to produce results.
2.3.6 The knowledge gap

The above résumé indicates that EF intervention is a developing research field that has plenty of scope for further work.

This researcher chose to develop an intervention targeting mental flexibility, or Shift, in early adolescence because a quality efficacy study (Karbach & Kray, 2009) had started to pave the way and interventions in educational settings have tended to involve younger children (Röthlisberger et al., 2012). The study specifically aimed to contribute by laying the foundations for a school-based EF intervention focussing on Shift skills in children who have moved into secondary education.

This researcher’s earlier work represented some first steps. In addition to the gathering of school staff perceptions reported above, a group interview was held to gather the views of EF experts\(^\text{12}\) regarding some collated Shift tasks that might form the basis of an intervention (Darby, 2013a). Many had been collated in line with Röthlisberger et al.’s (2012) strategy of using established EF measures, with others being harvested from material presented in University sessions. By discussing the task characteristics in some detail, as well as possible implementation issues and over-arching frameworks, the experts tutored this author in a number of dimensions to be considered in any further developments and that had not received sufficient thought at that early stage. Regarding the technical detail of tasks themselves, aspects suggested for consideration were skill blend, the manipulation of Shift difficulty, compatibility with EF development in adolescence, position in the Learning Hierarchy, attractiveness, social mediation, Flow and feedback.

The materials deemed most suitable by the experts were also trialled with a small group of Year 7 pupils (Darby, 2013b), working mainly in pairs, for one hour per week for six weeks. The pupils followed instruction sheets for and timed themselves on three different Shift tasks each week. The researcher led the sessions and a teaching assistant was also available. At the end of each session, the pupils gave brief written feedback on the tasks used that day. The researcher

\(^{12}\) These were all practising Educational Psychologists who either have postgraduate qualifications in neuroscience and/or who have carried out postgraduate level research into aspects of EF.
kept a diary of general impressions. This work served as a pilot study, an initial
gauge of how young adolescents would respond to such tasks in a school setting.
The most frequent reasons given for liking tasks were challenge and fun, including
the amusement created by unexpected mistakes. Critical comments most
commonly talked of the activities being too hard or poorly presented: font size,
card size and print colour. Overall, the tasks seemed to be pitched at an
appropriate level for these Year 7 pupils as they provided experience of tolerable
Shift difficulty. Factors appearing to contribute to enjoyment included task novelty,
using some creativity, working with a partner and measuring how long tasks took.
The students appeared to become increasingly proficient at following the
instruction sheets and could eventually work independently in their pairs for much
of the time (Darby, 2013b).

Taking these first steps did not change the rationale for the current research. The
gap remained: for an intervention targeting adolescent Shift skill that could be
delivered in a typical educational setting and that would produce meaningful
benefits. Rather this author was better placed to take the next important step and
restart the design process. The intention would now be to systematically develop
an EF intervention to include levels of Shift difficulty, taking into account additional
factors suggested by the pilot work. The nature of the intervention tasks was
anticipated to be similar: solving simple problems rather than complex information
manipulation. Nevertheless, the intention was to cover a broad range of Shift
challenge creating suitability for all young adolescents, to allow an inclusive stance
where all might benefit. This would also avoid ethical difficulties around singling
out groups of individuals with poorer executive functioning, as those most likely to
benefit (Diamond, 2012).

The specific research questions can be found at the end of this chapter, in Section
2.7.

2.4 The theoretical background

This section starts by attempting to provide a broad and sound theoretical
rationale for Shift intervention in adolescence that by deduction would apply to any
ensuing specific programme regardless of context. The endeavour is pursued
through engagement with current debate and accounts of EF development
including during adolescence.
Then this section reconsiders conceptions of EF by linking it with other cognitive models. The research journey should become evident, as the development of Shift skills becomes re-conceptualised as a complex intertwining and spiralling of skill within an EF of limited capacity. This analysis has implications for intervention mechanisms as well as likely programme outcomes.

The chosen EF model is further scrutinised with reference to research that threatens to undermine it. This leads on to other EF measurement discussion.

Finally through describing typical Shift tasks in detail, additional intervention mechanisms are identified, as well as a collection of candidate tasks.

As suggested above, the theoretical background is particularly important in terms of reflecting this researcher's journey. The intention is to capture an in-depth revisiting of literature that was needed before any programme development could take place.

**2.4.1 Are general cognitive functions theoretically amenable to intervention?**

The attempt to answer the question takes the form of responding to two further questions:

1. Should neuroscience inform interventions to be implemented in education?

   Ongoing debate about the applicability of neuroscience knowledge to the classroom informs the answer provided. General cognitive functions are considered, this to deliberately distinguish from, for example, long term memory that can be changed through the learning of specific facts and routines (Chein & Schneider, 2012).

2. How fixed is the developmental trajectory of general cognitive function and does research suggest optimum periods for intervention? The answer to this will look at what is known about typical EF/Shift development including neural changes during adolescence. It will also discuss reported EF heritability estimates.

**2.4.1.1 Should neuroscience inform interventions in education?**

Criticism has been levelled at applications of neuroscience to education, see below. One could perhaps avoid current debate by stating that an EF intervention is purely cognitive-behavioural. However, it seems important to try to ensure this research does not run counter to neuroscience findings and does not mis-use them.
The current debate seems to be at two levels. Firstly there is a general overarching debate that cautions against hasty and simplistic educational applications of neuroscience. Secondly, specific areas of application are critiqued. Here feelings seem to run high, as cherished notions are challenged.

The more general debate looks at how the two research disciplines differ, both in their territories (Willingham, 2009) and their specific use of language in discourse (Howard-Jones, 2008). Neuroscience studies the brain (and its biology) and makes links to the mind (and its cognitive skills), whereas education is interested in the mind and resulting behaviours (Anderson & Reid, 2009; Cubelli, 2009). Neuroscience tends to provide positivist biological descriptions of how/why change happens whereas education requires prescriptions of how to create change (general principles or specific interventions) within broadly social-constructivist conceptions of learning (Christodoulou & Gaab, 2009; Howard-Jones, 2008). Also, neuroscience tends to study simple devised laboratory tasks aiming to tap relatively few cognitive processes whereas education deals with the acquisition of complex knowledge and skills in relatively uncontrolled settings (Mason, 2009; Willingham, 2009).

A consequence of the differences has been for neuromyths to develop: popular accounts of brain function, that contain grains of truth from the research they have grown from, but where invalid extrapolations have been made (Geake, 2008). In one study (Howard-Jones, 2014), 48% of teachers were found to believe the neuromyth\textsuperscript{13} that people typically use only 10% of their brains at any one time and that boosting this percentage would create more/better learning (Geake, 2008). Educationalists keen to apply neuroscience to education have regularly fallen prey to being mis-sold interventions based on such neuromyths and are frustrated to find how few sound interventions exist (Goswami, 2006).

Not surprisingly, neuromyths have generated caution within the general debate\textsuperscript{14}. The way forward is suggested to be a continued research effort but with joint working to ensure proper interpretations, translations and evaluations (Howard-Jones, 2014), in short the bridging between the differing epistemological stances

\textsuperscript{13} This would suggest an ongoing training need, likely also to extend to perceptions of adolescent brain development.

\textsuperscript{14} Some positive balance is provided by Goswami (2004a, 2004b, 2006).
and viewpoints (Anderson & Reid, 2009; Howard-Jones, 2014). Cognition and therefore psychology clearly provides an interface (Howard-Jones, 2008). This idea will be picked up in Section 2.7, as part of a rationale for EP involvement.

Moving now to the specific debates. Wastell and White (2012) seem appalled at the way critical periods (a misinterpretation of sensitive periods) and mind-brain conflation have been used to build simplistic social policy on intervention for disadvantaged children. Somewhat differently, Apter (2012) strongly attacks evidence that appears to show Working Memory and its neural substrates can be strengthened to useful effect. As Working Memory is part of the same EF system as Shift (in the model adopted), this latter critique is useful to consider. It probably exists because Working Memory has attracted applied research leading to and sometimes linked with commercial interest (Klingberg, 2012). This aside, the criticisms potentially apply equally to Shift.

Apter (2012) is particularly critical of the CogMed intervention. He suggests that the research supporting it (e.g. Holmes, Gathercole, & Dunning, 2009) is flawed. It claims to have boosted capacity of Working Memory, which in most theoretical conceptions is of limited size. So either the apparent increases are due to participants adopting more efficient strategies or the research has been based on imperfect theoretical models. Also the methodologies used are weak. Training tasks are too similar to the measurement tools and studies have not had appropriate controls or sufficiently delayed post-measures and/or have not taken sufficient account of other potential explanatory variables including maturation. Finally, apparent brain changes have been attributed to the training programme.

Others are similarly critical, but with a focus more on the methodologies and lack of generalisable benefit (Hulme & Melby-Lervåg, 2012; Melby-Lervåg & Hulme, 2013; Shipstead, Hicks, & Engle, 2012). In response, Gathercole, Dunning and Holmes (2012) acknowledge methodological weaknesses, but suggest that most researchers cannot conduct Gold Standard studies immediately. An accumulation of flawed evidence is often needed first. Scepticism is wise, but promising ideas should not discarded without due consideration over time (Gathercole et al., 2012). Their research continues to report positive and lasting results from Working Memory training, including school-based interventions for children in middle childhood, albeit with mixed effects beyond Working Memory itself (Dunning, Holmes, & Gathercole, 2013; Holmes & Gathercole, 2013).
Stating the case more strongly, Klingberg (2012) insists that the evidence is solid regarding Cogmed. Nevertheless, the field is young with issues still to explore, such as finding out what interventions work best for whom (Klingberg, 2012). Diamond (2013) also argues that CogMed provides some of the stronger direct EF intervention evidence precisely because it includes studies using random assignment, active control groups and sound pre-/post- measures (e.g. Klingberg et al., 2005). Nevertheless, she draws the same overall conclusion as Apter (2012), that computerised Working Memory training currently shows limited generalisable benefits.

The issue of whether neuroscience should inform interventions in education is clearly important background to this study. This researcher's interpretation is that in the specific area of EF, the debate is in a difficult place. Claims of specific brain change after intervention (Klingberg, 2010) seem premature and unnecessary. More important is that improved cognitive performance (whether through capacity or strategy) does not seem to reliably create more general benefit. Yet given the acknowledged importance of EF and its constituent skills (e.g. Diamond, 2013), it would seem too early to abandon the research effort. Independently, Howard-Jones (2014) has reached much the same conclusion and this ties in with earlier thoughts concluding the pragmatic rationale (Section 2.3). Also, although informed by neuroscience, EF intervention research does not need exact biological explanations, but it does contribute to the applied research body demanded by the more general debate (Coch & Ansari, 2009; Greenwood, 2009).

2.4.1.2 How does EF develop and respond to the environment?

The potential to effect change within an individual's EF is explored through understanding typical EF development (both cognition and biology) and then a consideration of heritability.

2.4.1.2.1 The development of EF and its components

The magnitude of typical EF development appears to be greatest during early childhood, diminishing though continuing into at least adolescence (Anderson et al., 2002; Romine and Reynold, 2005; Best et al., 2011) and probably beyond into early adulthood (Taylor, Barker, Heavey, & McHale, 2013). The nature of this extended development is not simple to describe: changing patterns of performance and associated brain activity in older children have been interpreted
as reflections of emerging metacognitive strategy\(^{15}\) (Best et al., 2009), relative difficulty in resisting reward (Casey & Caudle, 2013) and increasing efficiency (Zottoli & Grose-Fifer, 2012). For example, there is a period in early adolescence when task reaction times increase to produce more accurate performance (Best et al., 2009; Best, Miller, & Naglieri, 2011; Best & Miller, 2010), whereas in late adolescence and even early adulthood, overt performance on tasks typically ceases to improve but brain activity continues to change (Crone, Donohue, Honomichl, Wendelken, & Bunge, 2006; Ezekiel, Bosma, & Morton, 2013; Luna, Padmanabhan, & O’Hearn, 2010).

Looking at EF development in more detail from a purely cognitive perspective, it is useful to take the Miyake et al. (2000) model of adult EF as a point of reference (Best & Miller, 2010). Variations in the Unity and Diversity mix during development (Best & Miller, 2010) are then arguably easier to see.

Early on, up to about the age of six, a single common EF component has often best accounted for performance on EF tasks (Bull et al., 2011; Hughes, Ensor, Wilson, & Graham, 2010; Hughes & Ensor, 2011; Wiebe et al., 2011; Willoughby et al., 2012). After that, sub-components become identifiable (Brocki & Bohlin, 2010; McAuley & White, 2011; Sluis et al., 2007). In particular, Duan et al. (2010) found they could identify the three Miyake et al. (2000) components in children aged 11 to 12 years.

A possible differing interpretation of data from young children is that Inhibition skills are developing quickly and therefore they exert the greatest effect on task performance at this point, giving rise statistically to a single explanatory component. This possibility fits with evidence showing that the EF component skill with the greatest predictive power changes with age (Davidson et al., 2006; Senn, Espy, Paul and Kaufmann, 2004) and that children as young as four can perform basic tasks requiring each component skill (Davidson et al., 2006). It also fits with other suggestions that the three components are intimately coupled in young children (Wiebe, 2014) and that skill development involves components bootstrapping each other and becoming better co-ordinated (Garon et al., 2008).

\(^{15}\) Metacognitive skill does not emerge for academic tasks before at least 8 years, it is still developing at 12 years and it may become more general over time, rather than domain specific (Van der Stel & Veenman, 2008, 2010).
This will be discussed again in the sections that reconsider conceptions of EF and that look at Shift tasks in detail (2.4.2).

Once EF components can be identified, their development can be separately tracked.

**Inhibition** is the first component to mature, such that only more recent computer-based tasks are sufficiently sensitive to pick up the fine tuning that is still occurring into adolescence (Best et al., 2009). Later reviews suggest more certainly that Inhibition is then still developing (Ikeda, Okuzumi, & Kokubun, 2013; Luciana, 2010; Romine & Reynolds, 2005) and that even when adult levels of performance are reached, they require more effort and may be slower (Luna et al., 2010).

**Working Memory** continues to mature into adolescence but capturing later development requires relatively complicated tasks (Best et al., 2009). Again, other review work suggests development is more extended (Luciana, 2010).

**Shift** develops up until the age of at least thirteen, the speed-accuracy trade-off strategies (see above) appearing to indicate the emergence of metacognition (Best et al., 2009). A study by Dumontheil et al. (2010) suggests that Switch task performance improves at least into late adolescence (17 years).

To recap so far, although EF seems to develop most quickly during early childhood, all component skills continue to improve during middle childhood and into adolescence and perhaps also into young adulthood.

Looking now at parallel changes in brain process, it is worth considering both measured activity and anatomical development. Taking the first of these, in broad terms it seems that activation patterns associated with EF develop in terms of their lateralisation and distribution (Levin & Hanten, 2005). The diffuse prefrontal activity seen in younger children becomes replaced by smaller more focal areas of sometimes more intense activation in adults (Best & Miller, 2010; Blakemore & Choudhury, 2006). This would appear to resonate with the fractionation pattern of cognitive development described above and some authors attempt to describe the accompanying brain activity change (Best & Miller, 2010). However, the use of different tasks and imaging methods make it difficult to identify consistent patterns (Levin & Hanten, 2005; Luciana, 2010).

---

16 Table A2.9 in Appendix 2.7 gives a flavour of the complication.
More typically brain changes are outlined at the level of overall EF. One pertinent example describes activity in prefrontal cortex (PFC) during creative problem solving tasks (Kleibeuker et al., 2013). In terms of performance, adolescents and adults were equally successful, with a slight creativity advantage for adolescents. Their greater recorded PFC activity was interpreted as reflecting this creativity, but also adults’ ability to process more efficiently (Kleibeuker et al., 2013), this being the later development not captured in overt task performance.

Turning to anatomical development, the following account focuses on EF in adolescence\(^\text{17}\). Within PFC grey matter volume increases as children approach adolescence, it peaks at eleven to twelve years and it then reduces until at least 22 years (Blakemore & Choudhury, 2006; Burnett et al., 2013). The peak is slightly earlier for girls (11.0 years) than for boys (12.1 years) (Burnett et al., 2013). Increases in grey matter volume are due to synapse proliferation (synaptogenesis), whilst reductions are thought to be caused by a loss in redundant or unused connections (synaptic pruning) (Blakemore & Choudhury, 2006; Bryck & Fisher, 2011; Goswami, 2004a). This is compatible with the more focussed patterns of brain activity described above.

Looking at underpinning mechanisms, Selemon (2013) notes a phase of increased long-term depression\(^\text{18}\) (LTD) in adolescence that predisposes neurons to synaptic pruning. He suggests this effectively creates enhanced environmental responsiveness, i.e. plasticity (Blakemore & Choudhury, 2006) and hence potential for additional EF development.

There are also changes in white matter volume in PFC, a linear steady increase throughout childhood and well into adulthood (Blakemore & Choudhury, 2006; Bryck & Fisher, 2011) produced by myelination (the formation of glial support cells) that effectively increases the speed/efficiency of existing circuitry (Bryck & Fisher, 2011). This could at least partially account for the efficiency gains accrued between adolescence and adulthood (Kleibeuker et al., 2013).

In addition, connectivity of PFC to other brain regions continues to be refined into adolescence (Burnett et al., 2013) and this parallels the more widely distributed

\(^{17}\) Earlier development in other brain areas, such as sensory cortex, can be thought of as having similar sensitive periods (Blakemore & Choudhury, 2006; Selemon, 2013).

\(^{18}\) See glossary.
patterns of brain activity that are observed (Levin & Hanten, 2005). Morton (2010) and Ezekiel et al. (2013) attribute EF development as much to this, as to increased localisation (synaptic pruning). This analysis fits with the results from work that attempts to lift the adult brakes on plasticity (Bavelier, Levi, Li, Dan, & Hensch, 2010). Specifically, Voss et al. (2010) found that sustained increased levels of physical activity in older adults improved cognitive function and that increased EF levels were particularly associated with increased connectivity.

Essentially then, these anatomical changes taking place in PFC during adolescence are an enhanced instance of the brain plasticity evidenced across the lifespan through new learning and recovery from brain injury (Chein & Schneider, 2012; Kolb, Gibb, & Robinson, 2003).

**Synthesizing the evidence**, it seems reasonable to suppose that Shift skills are typically available by eleven years (and possibly much earlier) and that visible Shift task performance plateaus at around 17 years, whilst fine tuning efficiency gains continue into early adulthood. Shift skill development in adolescence appears to be supported by PFC neural pruning and heightened environmental sensitivity.

A common sense approach suggests that intervention potentially works best when it can piggy-back on natural development (Elsabbagh, 2014). This was the rationale underpinning early intervention, since EF develops most quickly in early childhood (Röthlisberger et al., 2012). The argument for intervention in adolescence rests slightly differently on prolonged EF development providing later remediation opportunities for deficits spotted in early and middle childhood (Greenberg & Rhoades, 2008; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007; Pentz & Riggs, 2013; Pokhrel et al., 2013). As described above, the EF cognitive gains typically reported are smaller in adolescence than for early childhood\(^{19}\), but the known changes in adolescent PFC brain circuitry appear to offer the potential for accelerated development through intervention. This possible opportunity has been referred to as a second critical period for EF in adolescence (Greenberg & Rhoades, 2008). Invoking a ‘critical period’ and hence perhaps a neuromyth (Greenwood, 2009; Mason, 2009) seems unnecessary. Overall, EF development evidence seems to indicate that Shift skills in early adolescence (about 11 to 13

\(^{19}\) This description is for performance on tasks attempting to measure core skills. It does not extend to metacognition which would likely to show a different pattern over time.
years) are in an appropriate state for targeted intervention, since they exist but continue to develop.

Nevertheless difficult issues remain. For example, children who suffer early severe brain injury (Nadebaum, Anderson, & Catroppa, 2007) do not appear to catch up during adolescence. However this evidence of deficit is without specific EF intervention and Goswami (2004) and Bryck and Fisher (2011) suggest it is only in cases where input is very different (for example for blind people) that one can see how adaptive the brain can be. So children experiencing brain injury could be indicative of the current position of intervention research, that has yet to produce appropriate programmes of remediation input for them. Further, they may evoke different caregiving behaviours (Asbury & Plomin, 2014) that are not conducive to EF development. The question remains then as to whether all children are able to make full use of the theoretical opportunities for accelerated EF development in adolescence.

2.4.1.2.2 EF heritability

Individual differences in EF reflect substantial heritability, with twin data exhibiting general correlations of up to 0.75 (Friedman et al., 2006). Twin studies additionally suggest that Inhibition/Common EF is 99% heritable, Updating/Working Memory is 56% heritable and Shifting is 42% heritable (Friedman et al., 2008). Leve et al. (2013) also find that toddler EF is largely genetically determined and that genetics play a more important role than prenatal risk factors, such as substance abuse.

For this researcher, the word heritability initially had strong biological connotations and the figures above appeared to contradict the previously argued case for EF intervention. However, heritability is a statistically-based concept that perhaps exemplifies the clash of discourse encountered when evidence from one literature area is used by researchers from another. Independently, Morton (2010) has reached similar conclusions.

Asbury and Plomin (2014) usefully explain heritability and its implications. In essence, high heritability estimates arise when a large proportion of performance variation is accounted for by genetics. This tends to be the case where there is equality of access to shared experience and performance variation is reduced. The effect of shared experience can be huge but it is lost in the heritability calculations. Theoretically when an intervention is applied, performance could be
boosted for all children and average scores would increase. The extent of shared experience might not be affected, the range of performance could stay the same and heritability estimates would remain unchanged. This would be equally possible for skills with high and low heritability.

Hence Miyake & Friedman (2012) rightly emphasize that “high heritability does not mean immutability. Heritability is the portion of variability across individuals within a particular sample\(^{20}\) attributable to genetic effects at a particular point in time. Thus, it says nothing about the source(s) of a particular individual’s EF ability or the trainability of EFs within each individual or among a group of individuals. In fact, recent studies suggest that EF ability is amenable to some training effects” (Miyake & Friedman, 2012, pg. 11).

Reviewing the theoretical evidence so far, it seems that if sensitive periods of development create natural windows for intervention, then EF and Shift could/should be targeted during adolescence and estimates of heritability do not contradict this suggestion. However, applied research effort is needed to bridge the gap between accumulating neuroscience knowledge and attempts to support EF in the classroom.

2.4.2 A reconsideration of conceptions of EF

This section starts by looking at how the three component model of EF (Miyake et al., 2000) fits with other cognitive accounts. Then it considers whether confirmatory factor analysis can legitimately identify EF component skills, it explores other EF measurement issues and finally it examines what skills Shift tasks really require. In so doing, there is some further interpretation of the EF development literature and it becomes possible to give a developmental account of Shift that can later be used to underpin this research’s intervention and to order possible programme tasks.

2.4.2.1 How the three components of EF fit with other cognitive models

To recap, Miyake et al. (2000) defined three components within Executive Function:

\(^{20}\) Underlining indicates what was in italics in Miyake and Friedman’s paper (2012).
- Inhibition is the ability to suppress a dominant or automatic or prepotent response.
- Updating of working memory is the ability to maintain and manipulate information over brief periods of time.
- Shift is the ability to shift between mental states, operations, or tasks.

Given the considerable research effort dedicated over time to Working Memory and linked fields (e.g. Baddeley, 2000, 2012; Baddeley & Hitch, 1974; Broadbent, 1958) and the prominence of certain models (Baddeley, 2012; Baddeley & Hitch, 1974), there seems to be a lack of work explicitly linking Working Memory per se and the Working Memory of EF. Notable exceptions are provided by Baddeley himself (Baddeley, 2012) and Miyake and her colleagues (Miyake et al., 2000).

Baddeley (2012) gives an overview of Working Memory research suggesting that the principal role of the Central Executive is attentional control of action. It has limited capacity but is complex and proper description likely needs fractionation into several executive functions (Baddeley, 2012). Baddeley (2012) mentions candidate lists, including Miyake et al.’s (2000) model and his own: focussed attention, divided attention and task Switch.

The idea that Working Memory’s Central Executive and EF (including Working Memory component skills) are in fact synonymous is supported in a number of ways. Firstly, Working Memory as conceived in Baddeley’s work is primarily supported by dorsolateral prefrontal cortex (Chase, Clark, Sahakian, Bullmore, & Robbins, 2008), one of the main areas implicated in EF, see Appendix 2.3. Secondly, the skills within EF are arguably intimately bound up with each other. When the Working Memory requirements of a task are manipulated, performances on Shift or Inhibition aspects change predictably (Hester & Garavan, 2005; Soutschek & Strobach, 2013). EF tasks requiring significant Shift, Working Memory and Inhibition skills are the hardest (Davidson et al., 2006; Soutschek & Strobach, 2013), in line with EF having limited capacity. Thirdly, neuroscientists are suggesting that the brain’s supervisory system can be fractionated both by

---

21 There are others. Garon et al. (2008) see EF as a unitary construct, a central attention system affecting all EF operations, but again with partially and increasingly (with age) dissociable components. Jurado and Rosselli (2007) provide an overview of several different suggested EF fractionations.
behaviour and by anatomy even though the linking mechanisms are still to be fully understood (Gilbert & Burgess, 2008).

**Figure 2.3: A proposed model of Working Memory**

Fourthly, researchers ostensibly working in the field of Working Memory are producing multi-component models that appear to resonate with EF fractionation. For example, Oberauer and Hein (2012) present a three-embedded-components model: a reactivated part of long term memory, a smaller region of broad focus with limited capacity and a single item being given focussed attention. Whilst the components sound different from the Miyake et al. (2000) model, the proposed
associated skills are similar: Inhibition of the last item in focused attention, Switch of attention to a new item and the ability to Update broad focus appropriately. Similarly, Kane and McVay's (2012) account of Working Memory gives central importance to keeping a current task approach in mind whilst inhibiting unrelated thoughts and this is harder for more complex tasks. Both sets of researchers relate Working Memory capacity to the ability to keep the correct (and only the correct) information in mind.

Taking the idea of synonymous concepts further, Figure 2.3 shows how Baddeley’s (2012) current ideas on Working Memory could be integrated with the three component model (Miyake et al., 2000).

An outstanding difficulty with the model shown in Figure 2.3 is the potential for confusion between Working Memory the larger system, as per Baddeley (2012), and Working Memory skills relating to the active manipulation of information, as per Updating in the Miyake et al. (2000) model.

2.4.2.2 Issues regarding EF component identification and measurement

Success of an intervention in terms of outcomes is typically judged by score improvements on measures of the targeted skill. The literature so far has implied that EF is a set of abilities that constitute causative latent variables that will in part determine performance on EF tasks. The viewpoint is usefully illustrated by Figure 2.4, taken from Willoughby et al. (2014). Other causative variables impacting on EF task performance would include non-executive skills such as naming seen objects or pressing levers and modulators such as mood and time of day, as will be discussed later.

For a person to successfully carry out a Switch task, for example, they need at least set-Shift skills and perception/motor/lower cognitive skills (Friedman et al., 2008). The tasks of measuring EF skills and identifying underlying latent EF variables both carry this inherent task impurity problem, that higher-level functioning can only be observed or accessed through the lower-level processing it controls (Miyake et al., 2000). This is in addition to the impurity issue that EF tasks rarely, if ever, draw on a single EF skill. Hence studies exploring EF components tend to report low correlations between performances on tasks purportedly capturing the same skill (Miyake et al., 2000; Willoughby et al., 2014). The particular common executive functioning is in danger of being masked by the
noise created by extraneous non-executive variables (Miyake et al., 2000) and other executive skill requirements (Herd et al., 2014).

**Figure 2.4: A reflective multi-tiered measurement model, adapted from Willoughby et al., (2014)**

(Blue dotted arrows indicate the corresponding formative model.)

It was in an attempt to gain a window on EF latent variables that Miyake et al. (2000) used confirmatory factor analysis to identify common performance variance and hence confirm (theoretically) the underlying components of EF. To be able to justify structuring research around their model, the methods and assumptions used in its creation must be robust to critique.

Miyake et al. (2000) chose tasks, three per skill, to reflect the components they expected to find, based on previous research evidence: set-Shift, Updating of Working Memory and Inhibition of prepotent responses. Within each task set, they deliberately chose differing task types, presumably to ensure that common variance was due to the underlying EF skill rather than similar non-executive requirements.

In their confirmatory factor analysis (CFA) it was a three factor model that was best supported. There were moderate correlations between the factors, but basic task correlations were stronger within component task sets than between (Miyake et al., 2000). Hence CFA provided evidence for both Diversity (the three proposed
components) and some Unity. Miyake et al. (2000) then went on to use structural equation modelling to show how the three components uniquely contributed to several complex EF tasks.

The authors acknowledged that different presumptions about latent variables could have led to different task choices and hence a different proposed model (Miyake et al., 2000) and this potential flaw has been criticised (Blair & Willoughby, 2013).

Further, Willoughby et al. (2014) pursued their concerns by re-examining several CFA studies including the influential Miyake et al. (2000) research. They felt that as well as there being statistical problems stemming from the low performance correlations on tasks purporting to capture the same latent variable, there were theoretical issues: a reflective model assumption, in the face of a possible alternative, specifically formative task measures, again see Figure 2.4.

Their theoretical criteria could not arbitrate, so Willoughby et al. (2014) used an additional statistical tool: vanishing tetrads. If these combinations of task correlation coefficients did not disappear, this was taken as evidence that tasks were formative not reflective. About half the re-examined studies met their criteria for implying reflective tasks including Miyake et al.'s (2000) research.

For the moment then it would seem that the Miyake et al. (2000) model has earned reprieve and is sufficiently robust to be used in this research.

Nevertheless, Willoughby et al. (2014) and their commentators (Wiebe & McFall, 2014) suggest a need for further methodology development to help distinguish between the two frameworks since the conclusions that can be drawn from them are different, for example regarding heritability. In addition they suggest that EF research would ideally look for change in latent variable rather than task measure, but certainly should take more task measures and develop better ones.

This author suggests three responses to these papers. Firstly, tasks could be both causal and reflective within each component. For example, inhibiting a physical response and inhibiting an internal distractor thought both have a 'not doing-ness' in common, but they equally contribute unique ways of 'not doing' to create the full

\[ \text{components) and some Unity. Miyake et al. (2000) then went on to use structural equation modelling to show how the three components uniquely contributed to several complex EF tasks.} \]

\[ \text{The authors acknowledged that different presumptions about latent variables could have led to different task choices and hence a different proposed model (Miyake et al., 2000) and this potential flaw has been criticised (Blair & Willoughby, 2013).} \]

\[ \text{Further, Willoughby et al. (2014) pursued their concerns by re-examining several CFA studies including the influential Miyake et al. (2000) research. They felt that as well as there being statistical problems stemming from the low performance correlations on tasks purporting to capture the same latent variable, there were theoretical issues: a reflective model assumption, in the face of a possible alternative, specifically formative task measures, again see Figure 2.4.} \]

\[ \text{Their theoretical criteria could not arbitrate, so Willoughby et al. (2014) used an additional statistical tool: vanishing tetrads. If these combinations of task correlation coefficients did not disappear, this was taken as evidence that tasks were formative not reflective. About half the re-examined studies met their criteria for implying reflective tasks including Miyake et al.'s (2000) research.} \]

\[ \text{For the moment then it would seem that the Miyake et al. (2000) model has earned reprieve and is sufficiently robust to be used in this research.} \]

\[ \text{Nevertheless, Willoughby et al. (2014) and their commentators (Wiebe & McFall, 2014) suggest a need for further methodology development to help distinguish between the two frameworks since the conclusions that can be drawn from them are different, for example regarding heritability. In addition they suggest that EF research would ideally look for change in latent variable rather than task measure, but certainly should take more task measures and develop better ones.} \]

\[ \text{This author suggests three responses to these papers. Firstly, tasks could be both causal and reflective within each component. For example, inhibiting a physical response and inhibiting an internal distractor thought both have a 'not doing-ness' in common, but they equally contribute unique ways of 'not doing' to create the full} \]

\[ \text{At this point they wondered if the source of Unity might be the controlled attention needed in all tasks, or perhaps some aspect of Inhibition.} \]

\[ \text{Hence also the Inhibition component is retained.} \]
Inhibition picture. This situation would have statistical implications beyond the current understanding of this researcher.

Secondly, the task impurity problem is starting to be addressed. For example, Van der Sluis et al. (2007) included EF tasks all using Naming as the response method and Naming was a latent variable in their CFA. Similarly the Inhibition task in the NEPSY-II test (Developmental NEuroPSYchological Assessment for children aged 3 to 16) directly compares performances on Naming only tasks with Naming plus EF tasks, specifically Inhibition and then Inhibition-plus-Shift.

Thirdly, certain task formats appear repeatedly in the literature and as such have arguably come to represent the Shift component. Analysing what they require therefore allows access to the detail of what Shift means and to see how other EF and non-executive skills are co-opted for successful performance. It is hoped that this is not the same as assuming a formative stance, since this is the approach used shortly.

It remains in this section to briefly consider other measurement issues that are perhaps less central to the nature of Shift and its place within EF, but are nevertheless important in this research: test-retest effects and individual variation in EF performance according to mood and time-of-day.

Using a comparison of results from longitudinal studies with those from cross-sectional studies, Salthouse (2014) argues that participants’ experience from baseline testing acts to inflate their scores at follow-up testing, even with several years in between. Whilst his data are limited and individual differences cannot be eliminated as an important factor, Salthouse (2014) rightly highlights the test-retest issue. In this research, an intervention study, longitudinal data are clearly almost inevitable and so it is important to be conservative in interpreting results and to use the test-retest information given in test manuals to this end.

Dealing with potential individual variation in EF performance may be more difficult. Generally young people concentrate better at their optimal time of day (Lara, Madrid, & Correa, 2014) and adolescents more specifically (11 to 14 years) perform better on EF tasks at their preferred time of day (Hahn et al., 2012). In this research, this effect would likely be best dealt with through always testing

---

24 Miyake et al. (2000) report that others have suggested the lesser use of EF in non-novel tasks as an alternative reason for retest unreliability.
students at the same time. Yang and Yang (2014) have also showed that mood has an effect on children’s EF task performance. They induced mild positive affect and this boosted performance on a cognitive flexibility task. Pnevmatikos & Trikkaliotis (2013) instead manipulated frustration levels in 8 to 12-year-olds and found the induced within-child differences were greater than between-child differences. Willoughby et al. (2014) suggest that immediately previous task demands and arousal levels affected by sleep, food and stress all affect EF task performance in idiosyncratic ways, such that reliable measurement is difficult. This researcher would suggest her best response to this evidence is a general checking-out before testing a child and if necessary suggesting they return another day.

2.4.2.3 A detailed exploration of typical Shift tasks

As indicated earlier, the aim of this analysis of typical Shift tasks was to give a better understanding of what Shift means: “it is widely assumed that Shifting or Switching task-set entails specific demands on cognitive control processes” (Waszak et al., 2003, pg. 362) and Shift is a construct that needs “to be operationally defined by the tasks used to measure it” (Koziol, 2014, pg. 161). The exploration is at a relatively detailed cognitive-behavioural level.

Two typical concrete examples are presented so that associated phenomena are understood more easily. The colour/shape contingency naming task (Miyake & Friedman, 2012) uses stimuli as shown in Figure 2.5 below.

**Figure 2.5: Stimuli examples from a typical Shift task**

C and S are cues for the task to be undertaken: name the colour or the shape respectively. In most computer-based trials, responding is by lever press, for example, left for red or circle and right for blue or triangle.
Similarly, the Stroop contingency naming task (e.g. Waszak et al., 2003) could include the stimuli shown in Figure 2.6 below.

**Figure 2.6: Stimuli examples from a typical Stroop task**

<table>
<thead>
<tr>
<th>C</th>
<th>W</th>
<th>W</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORANGE</td>
<td>BLUE</td>
<td>YELLOW</td>
<td>RED</td>
</tr>
</tbody>
</table>

C and W are cues for the task to be undertaken: name the colour or the word respectively. This task contains prepotence asymmetry, as giving the word is the more automatic prepotent process/response. It also contains congruent and incongruent stimuli. BLUE is congruent whereas RED is incongruent. Prepotence or dominance is established through experience. For literate individuals, the dominance of reading a word over giving its colour develops until about 7 or 8 years (Ikeda et al., 2013).

Essentially multiple task-sets (effectively schemas) are invoked in response to stimuli (Monsell, 2003). “Shifts between intrinsically competing tasks produce substantial performance costs” (Waszak et al., 2003, pg. 362). Can be processed by both the -colour and the -shape task-sets. Measures are typically error rates and reaction times.

The recognised associated phenomena are compiled in Table 2.1 for convenience and they can be manipulated experimentally (Waszak et al., 2003).

For the theoretical underpinning of this research, it is important to identify the skills/cognitive processing required for successful Shift-task performance.

There seems to be agreement that task-Switch phenomena reflect the bidirectional interplay between exogenous and endogenous control. Exogenous control refers to the stimulus typically evoking multiple habitually associated task-sets. This is reflected in the residual Switch-cost that cannot be eliminated even with long cue-stimulus intervals (Monsell, 2003; Waszak et al., 2003). Endogenous control refers to the mind engaging the right task-set to process the anticipated stimulus.
This is reflected in the Switch cost reductions seen when the cue-stimulus interval is increased.

**Table 2.1: Phenomena measured in Shift/Switch research.**

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mixing Costs</strong>. <strong>Switch Costs.</strong></td>
<td>These are the increased error-rates and reaction times for mixed blocks of items (some for each task) compared with blocks of items of a single task. Mixing costs are said to reflect the effort of retaining and using two rules/task-sets rather than one. Switch costs decrease as children grow older.</td>
</tr>
<tr>
<td>a) Residual Switch cost.</td>
<td>Active preparing for Switch reduces Switch cost but never eliminates it. This can be done for example, by giving a cue before rather than with the stimulus and giving an interval between the cue and the stimulus. What is left is known as the residual Switch cost. Children seem to benefit more from having an interval to prepare; it seems to reduce impulsivity.</td>
</tr>
<tr>
<td>b) The main Switch cost occurs for the first item after task Switch but a much smaller cost still exists thereafter. (Gilbert and Shallice (2002) disagree and say that once Switched a person is fully Switched, under most experimental conditions.)</td>
<td></td>
</tr>
<tr>
<td>c) Asymmetric Switch costs.</td>
<td>Where one response is relatively dominant or prepotent, Switch to this dominant response carries a greater Switch cost than from it – in most experiments. Undoing the Inhibition of a dominant response is said to be more difficult/effortful. This is referred to as asymmetric Switch cost.</td>
</tr>
<tr>
<td>d) There is a residual switch cost even where Switch is to a congruent stimulus.</td>
<td></td>
</tr>
<tr>
<td>e) Passive dissipation of the previous task-set reduces Switch cost. This can be enhanced by increasing the interval between one item and the cue for the next.</td>
<td></td>
</tr>
<tr>
<td>f) Restart cost effect. The restart cost effect after an interval between repeat-task trials is similar to Switch costs, so long as the stimuli have previously been used in a conflicting task, i.e. one that evokes multiple task-sets.</td>
<td></td>
</tr>
<tr>
<td>3. Some authors distinguish between Switch and Shift tasks. Huizinga &amp; van der Molen (2011) define a Switch task as the swapping between the type of stimulus processing usually as directed by item cues (e.g. C or S) and a Shift task as the swapping between response type also usually by cue such as respond versus don’t respond (X is additional cue). This author believes task-set Shift, albeit of different kinds, would seem to be needed for both task type changes and see Garon et al. (2008).</td>
<td></td>
</tr>
</tbody>
</table>

The interplay is needed to appropriately manage the conflict induced by using stimuli that invoke more than one stimulus-task-set pairing and this is itself a form of Executive Control (Waszak et al., 2003). The extents to which the interplay involves EF and is more/less heavily controlled by endogenous factors are moot points (Gilbert & Shallice, 2002; Huizinga et al., 2007; Kalanthroff & Henik, 2013).
To summarise so far, the basic Switch stimulus appears to provoke bottom-up processing of more than one stimulus feature (colour and shape for instance) that in turn invokes multiple stimulus-task-set pairings. More or less consciously, top-down conflict resolution allows successful task performance, through full engagement of the appropriate task-set held in mind and inhibition/suppression of others. It seems then that Shift skill requires a dynamic interplay between at least the Working Memory and Inhibition EF components (Best & Miller, 2010; Diamond, 2012; Garon et al., 2008; Hoffman & van Dillen, 2012; Levin & Hanten, 2005; Morton, 2010, 2014; Oberauer & Hein, 2012).

A number of authors have investigated this interplay specifically with young children, thereby adding cognitive behavioural detail to what is understood by Shift development. For example, Zelazo and Diamond have manipulated the stimuli used in the Dimensional Change Card Sort task to remove the usual processing conflict (Diamond, Carlson & Beck, 2005; Zelazo & Frye, 1998; Zelazo et al., 2003). Usually three year olds perseverate, that is they will sort pictures by the old rule (for example big vs. small) despite knowing the new rule (for example red vs. blue). If processing conflict is removed (for example by changing a big red car to a big black car on a red background) then young children can demonstrate Shift skills some six months earlier. Diamond and Zelazo and their colleagues interpret this success as being due to the removal of the need to inhibit a competing task-set invoked by the stimulus.

By contrast, Munakata, Snyder and Chatham (2012) found that good Switchers are able to give the new rule more quickly, this suggesting they are better at keeping the new task-set in mind: a Working Memory skill.

Put together, these differing developmental accounts again suggest that successful performance on typical Switch tasks requires Working Memory and Inhibition skill, but that if these requirements are reduced, young children can demonstrate a basic “purer” Shift skill.

The interplay of EF component skills needed for success on typical Shift tasks is also explored by Herd et al. (2014), but rather differently. They highlight the statistical differences between the two Miyake models (2000, 2012). Miyake et al. (2000) identified three non-orthogonal components that cannot be fully separated and therefore reflect some shared skill: Shift, Updating and Inhibition. By contrast,

Herd et al. (2014) used a neural network model to indicate that Shift-specific skills involve task persistence or ‘stickiness’; less stickiness gives better flexibility, but this is a trade-off with behaviour stability. This finding ties in with less cited results, that Shift skill has, at times, been negatively correlated with EF as a whole (Friedman et al., 2008).

The earlier Shift component must therefore be composed at least of common EF plus Shift-specific skill (Herd et al., 2014).

Overall then, a slightly different spin to the notion of EF development has been developed. It seems that rudimentary or emergent component skills are available to children as young as three years. Perhaps initially they are so close-coupled that statistically they appear as one (Wiebe, 2014), although this author would suggest that earlier greater development of Inhibition is also still a viable explanation.

EF development is then seen as gradual fractionation of skill (or at least individual skills become measurable), mutual bootstrapping and improved coordination, all within a Central Executive of limited, but increasing capacity (Davidson et al., 2006; Garon et al., 2008). This fits with the conception of EF offered as a reconciliation of the later work of Baddeley (2012) with that of Miyake and her colleagues (2000, 2012). Work to boost Shift skill would almost certainly therefore impact on all EF, not through generalisation with far reach, but because the skills are inter-related (Gao, Peng, & Wen, 2014).

There are implications for Switch-like tasks. They will be most difficult where limited EF resource is being taken up with Working Memory and Inhibition demands, either within the Switch tasks themselves, or in parallel tasks (Davidson et al., 2006; Hester & Garavan, 2005; Soutschek & Strobach, 2013). Switch task training is likely to affect all the EF component skills, because firstly Switch tasks use them all (Diamond 2012) and secondly common limited resource may become more efficiently used and/or coordinated. Karbach and Kray (2009) suggested that their Shift training had perhaps improved task-set selection (arguably a Shift skill), goal maintenance (probably a Working Memory skill) and suppression of irrelevant stimulus features (likely an Inhibition skill).
Having adjusted her conception of Shift and what it means to improve Shift skills, certainly by the time children are in early adolescence, it remains for this author to pull out some fine detail from Switch-task research to inform the theoretical structure of a Shift intervention. The key additional papers used (Davidson et al., 2006; Huizinga & van der Molen, 2007; Ikeda et al., 2013; Kalanthroff & Henik, 2013; Kalanthroff, Goldfarb, Usher, & Henik, 2013) are referred to where appropriate; brief outlines of each are included in Appendix 2.8 rather than creating distraction here.

Firstly, the basic Shift-/Switch-task paradigm is shown in diagram form, in Figure 2.7. Then some skills and factors affecting the initial processing of a typical visual Shift item are summarised in Figure 2.8 and factors influencing the choice and use of response to a Shift item are summarised in Figure 2.9. Ideas from these three figures are drawn together to create a list of ways to manipulate Shift-task difficulty, see Table 2.2. Having the means with which to vary Switch-task difficulty in ways that acknowledge the intertwining of the EF component skills should provide some basis for a soundly structured intervention.
Successive visual stimuli are presented, each of which must be responded to according to a rule. The rule typically changes a number of times within a block of trials. Specific examples of the Switch task paradigm can be found in Appendix 2.9.

**Figure 2.7: Basic Shift-task paradigm**

Visual stimulus is presented, usually after or with a task cue. Several stimulus dimensions are processed, invoking a number of stimulus-task-sets.

Endogenous vs. exogenous process interplay

The relevant dimension and associated stimulus-task-set is privileged by Working Memory.

Inhibition of inappropriate responses (Ikeda et al., 2013)

Response is made
For congruent stimuli the two task-sets are not in informational conflict, because they produce the same information. (For example blue produces the same information whether the word is read or the colour noticed.) However for incongruent stimuli the two kinds of information are in conflict (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress distraction from within: irrelevant cognitions which could include now redundant task-sets (Ikeda et al., 2013)

For a Switch item, Executive Control must force the effortful Shift between stimulus-task grooves and Working Memory must privilege the new stimulus-task pair (task-set) (Davidson et al., 2006). This is made easier (and requires less EF) if the critical stimulus dimension is predictable ie task switching is regular (Kalanthropf & Henik, 2013). At its easiest, tasks are presented in single task blocks, with Switch only occurring between blocks. It is also easier for congruent stimuli (Kalanthropf & Henik, 2013).

The bottom-up invoking of task sets can be reduced by changing the relative salience of the stimulus dimensions (Fisher, 2011), ensuring that stimuli for the new task have either not been seen before (Waszak et al., 2003) or they share no common features/dimensions with items used for the old task (Diamond, Carlson & Beck, 2005) and by neutralising the content associated with a dimension (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress previously relevant, but now irrelevant, stimulus-task pairings (Davidson et al., 2006). Put slightly differently, one must selectively attend just to the relevant stimulus dimensions and this is easier for those with better Inhibition skills (Kalanthropf & Henik, 2013).

For congruent stimuli the two task-sets are not in informational conflict, because they produce the same information. (For example blue produces the same information whether the word is read or the colour noticed.) However for incongruent stimuli the two kinds of information are in conflict (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress distraction from within: irrelevant cognitions which could include now redundant task-sets (Ikeda et al., 2013)

For a Switch item, Executive Control must force the effortful Shift between stimulus-task grooves and Working Memory must privilege the new stimulus-task pair (task-set) (Davidson et al., 2006). This is made easier (and requires less EF) if the critical stimulus dimension is predictable ie task switching is regular (Kalanthropf & Henik, 2013). At its easiest, tasks are presented in single task blocks, with Switch only occurring between blocks. It is also easier for congruent stimuli (Kalanthropf & Henik, 2013).

The bottom-up invoking of task sets can be reduced by changing the relative salience of the stimulus dimensions (Fisher, 2011), ensuring that stimuli for the new task have either not been seen before (Waszak et al., 2003) or they share no common features/dimensions with items used for the old task (Diamond, Carlson & Beck, 2005) and by neutralising the content associated with a dimension (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress previously relevant, but now irrelevant, stimulus-task pairings (Davidson et al., 2006). Put slightly differently, one must selectively attend just to the relevant stimulus dimensions and this is easier for those with better Inhibition skills (Kalanthropf & Henik, 2013).

For congruent stimuli the two task-sets are not in informational conflict, because they produce the same information. (For example blue produces the same information whether the word is read or the colour noticed.) However for incongruent stimuli the two kinds of information are in conflict (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress distraction from within: irrelevant cognitions which could include now redundant task-sets (Ikeda et al., 2013)

For a Switch item, Executive Control must force the effortful Shift between stimulus-task grooves and Working Memory must privilege the new stimulus-task pair (task-set) (Davidson et al., 2006). This is made easier (and requires less EF) if the critical stimulus dimension is predictable ie task switching is regular (Kalanthropf & Henik, 2013). At its easiest, tasks are presented in single task blocks, with Switch only occurring between blocks. It is also easier for congruent stimuli (Kalanthropf & Henik, 2013).

The bottom-up invoking of task sets can be reduced by changing the relative salience of the stimulus dimensions (Fisher, 2011), ensuring that stimuli for the new task have either not been seen before (Waszak et al., 2003) or they share no common features/dimensions with items used for the old task (Diamond, Carlson & Beck, 2005) and by neutralising the content associated with a dimension (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress previously relevant, but now irrelevant, stimulus-task pairings (Davidson et al., 2006). Put slightly differently, one must selectively attend just to the relevant stimulus dimensions and this is easier for those with better Inhibition skills (Kalanthropf & Henik, 2013).

For congruent stimuli the two task-sets are not in informational conflict, because they produce the same information. (For example blue produces the same information whether the word is read or the colour noticed.) However for incongruent stimuli the two kinds of information are in conflict (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress distraction from within: irrelevant cognitions which could include now redundant task-sets (Ikeda et al., 2013)

For a Switch item, Executive Control must force the effortful Shift between stimulus-task grooves and Working Memory must privilege the new stimulus-task pair (task-set) (Davidson et al., 2006). This is made easier (and requires less EF) if the critical stimulus dimension is predictable ie task switching is regular (Kalanthropf & Henik, 2013). At its easiest, tasks are presented in single task blocks, with Switch only occurring between blocks. It is also easier for congruent stimuli (Kalanthropf & Henik, 2013).

The bottom-up invoking of task sets can be reduced by changing the relative salience of the stimulus dimensions (Fisher, 2011), ensuring that stimuli for the new task have either not been seen before (Waszak et al., 2003) or they share no common features/dimensions with items used for the old task (Diamond, Carlson & Beck, 2005) and by neutralising the content associated with a dimension (Kalanthropf & Henik, 2013).

Inhibition skills are also needed to suppress previously relevant, but now irrelevant, stimulus-task pairings (Davidson et al., 2006). Put slightly differently, one must selectively attend just to the relevant stimulus dimensions and this is easier for those with better Inhibition skills (Kalanthropf & Henik, 2013).
Table 2.2: How to manipulate Shift-task difficulty

1. **Provoke a partial versus complete task Switch** (Davidson, Amso, Anderson, & Diamond, 2006): multiple stimulus-task pairings are potentially invoked and task-set Shift is harder. This is the case in all but the most artificial situations (Kalanthropp et al., 2013) and includes:
   - the classic Switch-task paradigm using the same stimuli for different tasks, such that different dimensions become successively relevant (e.g. Diamond, Carlson & Beck, 2005).
   - changing some of the responses required in a task. For example, adding in GO/NOGO response types (Huizinga & van der Molen, 2011).
   - requiring the same responses to different tasks, for example Davidson et al.’s (2006) 6 Abstract Shapes, where identification of three different items all require the same key press.

2. **Alter the Working Memory requirement.**
   To make task-set Shift easier, the Working Memory requirement is reduced by:
   - providing a meaningful cue for the rule to be used, such as ‘W’ cues to read word.
   - providing a reminder for the response expected for each stimulus decision.
   To make task-set Shift harder, the Working Memory requirement can be increased by:
   - giving more rules. Children as young as four years can manage to keep in mind two rules if they are not being asked to inhibit a prepotent response (Davidson et al., 2006).
   - adding in parallel Working Memory tasks (Hester & Garavan, 2005).
   - making the Switch-task composite. For example, Gopher, Greenshpan and Armony (1996) had main tasks of evaluating the size of a number or the number of digits, with a change in response emphasis between accuracy and speed; both Switch types exacted a cost. Alternatively, Huizinga and van der Molen (2011) had main tasks of evaluating shape or colour, with a change in response mode between always giving an answer and with holding a response in specified situations (GO/NOGO).

3. **Manipulate the Inhibition requirement.** To make task-set Shift harder, the Inhibition requirement can be increased by including stimulus-task pairings that involve prepotent or previously well learnt responses (Ikeda et al., 2013), although this effect is reduced with increasing age (Davidson et al., 2006).

4. **Vary the predictability** and number of repeat trials between task Switches (Davidson et al., 2006; Huizinga & van der Molen, 2011). Single task trial blocks aside (which are the easiest), having more repeats between Switches and unpredictable task Switches make Shift harder.

5. **Vary the relative saliencies** and weightings of stimuli dimensions. It is harder to Switch to a task where the saliency of the newly relevant stimulus dimension is lower, especially for young children (Fisher, 2011). Also, it is harder to Switch when all relevant dimensions have very few values, as the weighting given to each is greater (Fisher, 2011).
Choosing and using the right response

Incorrect responses must be suppressed. This is particularly difficult where they are prepotent. Releasing this suppression is hard, perhaps especially for older children and adults – see (Davidson et al., 2006) and leads to the counter-intuitive asymmetric switch costs, if some responses are prepotent and some are not.

Prepotence can be trained through previous use as the appropriate response within a task-set.

Having the same correct response for several tasks is difficult especially for young children (Crone et al., 2006), perhaps because of the Working Memory load (Davidson et al., 2006).

Natural prepotency:
- The GO-NOGO paradigm: to respond is more instinctive than to not.
- The Simon Effect: to respond on the ‘same side’ as the stimulus is more instinctive.
- The Stroop Effect: to read a word is more instinctive than to give its colour. (Davidson et al., 2006)

This section finishes with a table of tasks, Table 2.3, that were considered as possible training tasks after the earlier pilot work (Darby, 2013a,b).

**Table 2.3: Tasks retained after pilot work**

<table>
<thead>
<tr>
<th>Activities based on tasks harvested from Yeniad et al.'s, (2013) study:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic trailmaking - from Tombaugh, 2004*</td>
</tr>
<tr>
<td>Cheese and mice trailmaking – from Monette, Bigras &amp; Guay, 2011*</td>
</tr>
<tr>
<td>2 colour trailmaking - from McLean &amp; Hitch, 1999*</td>
</tr>
<tr>
<td>Verbal Sequences - from McLean &amp; Hitch, 1999*</td>
</tr>
<tr>
<td>Picture sorting - from Blair &amp; Razza, 2007*</td>
</tr>
<tr>
<td>Picture sorting, something’s the same – from Vitiello, 2009*</td>
</tr>
<tr>
<td>Contingency naming: several variations – from Miyake &amp; Friedman, 2012*; Altemaier et al., 2006; Espy et al., 2004; Sluis et al., 2007*</td>
</tr>
<tr>
<td>Flanker – from Diamond et al., 2007*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities harvested from standardised assessments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knock and Tap – from NEPSY-I*</td>
</tr>
<tr>
<td>Word Generation – from NEPSY-II</td>
</tr>
<tr>
<td>Contingency playing card naming – from NEPSY-II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Others:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fizz Buzz</td>
</tr>
<tr>
<td>Problem solving based on flexibility promotion tasks – from Dawson and Guare, 2010*</td>
</tr>
<tr>
<td>Visual Illusions*</td>
</tr>
<tr>
<td>Stroop *</td>
</tr>
</tbody>
</table>

During pilot work, switching between two or more of the above activities was suggested as a composite task.

* This task was tried out by Year 7 students in the pilot work.
2.4.3 Additional relevant research

As suggested during previous work (Darby, 2013a), research areas were visited outside of the immediate Executive Function literature. These were: The Learning Hierarchy, Flow, comic strip conversations and social mediation and cooperative learning. Each was useful for identifying potential design features, but, with the exception of social mediation and cooperative learning, they were not central to the intervention structure or proposed mechanisms of benefit. Consequently, the summary diagram created for social mediation and cooperative learning is produced below, in Figure 2.10, whilst the others are presented in Appendix 2.10. Figure 4.5 in Chapter 4 summarises how all the areas were to be incorporated into the prototype design.
Figure 2.10: Principles offered by social mediation and cooperative learning

**Cooperative learning** (i.e. no competition) in pairs and small groups seems to promote higher achievement, a greater sense of academic support and the additional benefit of increased social self-esteem (Bertucci, Johnson, & Johnson, 2010; Bertucci, Johnson, Johnson, & Conte, 2012). Older children also benefit from **vicarious learning**, particularly in terms of picking up additional strategies (McGivern, Levin, Pressley, & Ghatatala, 1990).

Even **social presence**, the sense that others are working on the same tasks, can improve learning outcomes (Lee, Jeong, Park, & Ryu, 2011).

However, **pupil dynamics need to be managed** so as to avoid:
- friction (this erodes interest and engagement) (Walberg, 1969)
- some pupils feeling they are of lower status (Matthews & Cobb, 2005).

Intervention could use paired and small group learning, but this must be managed to avoid negative interactions.

---

**Social mediation and cooperative learning**

Using Vygotsky’s notion of the zone of proximal development (ZPD), all higher order psychological functions can be seen as firstly located within social interaction, before being internalised by individuals (Enyedy, 2003). These interactions may use productive conflicts and interpersonal and intrapersonal resolution to create cultural norms of understanding; the social resolution is an added incentive to create learning (Enyedy, 2003).

Intervention should use social dynamic to create interactions to house Shift (at a level that is tricky for the individual) until it is internalised.

---

**Dialogic conversation**, a concept that suggests exploratory talk between people is a creative space of reflection (Wegerif, 2008), can be used to develop children’s ‘me-cognition’ i.e. metacognition (Fisher, 2007).

Intervention should promote creative conversation.

---

The accepted **discourse** of the classroom mediates the **construction of word meaning** (Elbers & de Haan, 2005). A sample of the literature using the idea of discourse, this paper underlines the importance of setting up suitable discourse, to support later learning.

Similarly Billett (2009) suggests that learning experiences comprise a negotiation between the immediate social and physical world, individuals’ previous experience and facts such as their level of maturation.

Intervention must work within a complex social environment and with whatever individuals bring. This would be facilitated by explicit work on appropriate discourse.

---

**Effective socially mediated strategies** for improving learning include:
- **reciprocal teaching**, where students take turns to be teacher, this forcing them to summarise what they know. This is linked to improving **metacognition**: awareness of inconsistency and self-questioning are particularly effective. (Hattie, 2009).

Peer tutoring also seems to help with **skill generalisation** (Weili, Duan & O’Brien, 1998).

Several **teacher-mediated classroom variables are key** to engaging students and helping them to learn:
- setting **clear** learning intentions
- setting transparent success criteria
- making **learning visible** (Hattie, 2009). This includes **feedback**, crucially to make the teacher aware of students’ knowledge and understanding to inform future planning – hence formative assessment is important (Hattie, 2009). Feedback can be effective in children as young as 2 years, where the crucial element seems to be reflecting on the different possible rules to follow. More generally in school, feedback constitutes one of the main influences on learning if it signposts: the journey ahead, the next place on that journey and how to get there (Hattie & Timperley, 2007).

Intervention should give clear feedback about the learning journey and opportunities for students to be teacher and practise their meta-cognitive skills.
The next section covers the final area of literature in this review: implementation and evaluation research.

2.5 Implementation and evaluation research

This section aims to locate the study within a development process that stretches from an initial proof of concept through to (the ideal of) a robust intervention programme that works within specified settings. In turn, this should suggest commensurate evaluation criteria and some implementation issues to reconsider in later reflections.

Locating this study first of all, there appear to be two somewhat separate but overlapping research areas:

- **Implementation research.** Greenberg et al. (2005) define the stages of program development as:
  
i) Efficacy trials that focus on proof of concept and are highly controlled and ideally take the form of randomised controlled trials (RCTs).
  
ii) Effectiveness trials, where research takes place in real-world settings, ideally using the staffing and other resources typically available. At this stage, the quality of implementation becomes an issue. As such, these studies have a valuable contribution to make even though the results can be disappointing.25
  
iii) Going to scale, where an intervention becomes part of the normal toolkit. Implementation issues are extremely important at this stage.

Within implementation research the implied pathway seems to be unidirectional through the three stages.

This study involves some proof of concept (being a new intervention) but takes place in a real-world setting; it is therefore a part-efficacy, part-effectiveness trial.

- **Evaluation research.** An evaluation has been defined as a systematic assessment of program operations (i.e. processes) and outcomes, as a means of contributing to improvement (Weiss, 1998) or as a systematic study carried out in order to judge or improve an object (that could be an intervention) (Stufflebeam & Shinkfield, 1985). Stufflebeam (1983) asserts that the collection of quantitative information is insufficient and he outlines the CIPP

25 Lendrum & Humphrey (2012) suggests that both the efficacy and effectiveness trials are often missing in UK intervention implementation.
model (context, input, process, product) as a structure to provide appropriate background qualitative information against which to interpret quantitative findings (Mertens, 2005; Lendrum & Humphrey, 2012).

Contextual information would include the intended population needs (and underlying issues) and any opportunities to address these needs. Input information would include the system capacity to support intervention. Process information would include identifying where the intervention-as-planned is defective and where there are additional implementation faults. Finally, Product information would involve relating outcome information to the CIP information outlined above and making a judgement about product worth (Stufflebeam, 1983; Stufflebeam & Shinkfield, 1985).

There is an implication here both that some kind package exists, but also that the development process is bidirectional/cyclical, such that evaluation informs intervention refinements as well as implementation strategy (Langberg et al., 2011). Nevertheless, or even as such, evaluations take place at different points in the development process. An early evaluation, or evaluability assessment, would need to indicate sufficient worth for a larger scale study (Weiss, 1998) by showing that an intervention:

a) operates as intended and that this stands up to logical and theoretical scrutiny

b) seems to be relatively stable i.e. can operate reasonably smoothly within the intended environment and

c) produces some positive results on some limited measures (Weiss, 1998).

This study would appear to be exactly such an early stage evaluability assessment and the three associated evaluation criteria above seem appropriate.

So, both evaluation and implementation research would locate this study within their earlier stages, but nevertheless at a point where implementation and contextual issues, such as dosage, fidelity and adaptation, are crucial to consider when interpreting apparent outcomes (Durlak & Dupré, 2008; Greenberg et al., 2005).

Turning back to the implementation research, this typically focuses on effectiveness trials that examine a programme when delivered in a particular setting (Durlak & Dupré, 2008). In a review of meta-analyses covering over 500
studies, Durlak and Dupré (2008) set out an ecological framework for understanding effective implementation see Figure 2.11.

**Figure 2.11: Ecological framework for understanding effective implementation**

![Ecological framework for understanding effective implementation](image)

(Durlak & Dupré, 2008, pg. 335)

Each layer or component of the model has factors and characteristics associated with it and these are suggested to be common to at least most implementations. Table 2.4 is a version of Durlak and Dupré’s (2008) list with notes added in from education research. For any particular program it would seem important to identify its critical components and how these interact with specific context (Lendrum & Humphrey, 2012), so that appropriate facilitating strategies can be identified before the stage of wide dissemination (Lendrum & Humphrey, 2012).

Arguably, this taxonomy and description of implementation underplays the fact that any context is a complex human system (Bisset, Potvin, & Daniel, 2013; Kehle, Bray, & Nastasi, 1996). Facilitators will privilege certain intervention strategies according to their perception of local need (Bisset et al., 2013) and local adaptation will occur (Durlak & Dupré, 2008). Looking specifically at what secondary school staff might see as important locally, earlier findings (Darby, 2013a) indicated their perceived need to prioritise learning that impacts directly on results\(^\text{26}\).

---

\(^{26}\) All earlier findings (Darby, 2013, a, b) are reiterated in Figure 2.12 below.
Table 2.4: Factors and characteristics that affect implementation (Durlak & Dupré, 2008) *(Insertions from other research are in italics)*

<table>
<thead>
<tr>
<th>I. Community Level Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Prevention Theory and Research</td>
</tr>
<tr>
<td>B. Politics</td>
</tr>
<tr>
<td>C. Funding</td>
</tr>
<tr>
<td>D. Policy</td>
</tr>
<tr>
<td><em>Parent support has positive impact (Dulaney, 2012).</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Provider Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Perceived Need for Innovation: extent to which the proposed innovation is relevant to local needs.</td>
</tr>
<tr>
<td>B. Perceived Benefits of Innovation: extent to which the innovation will achieve benefits desired at the local level</td>
</tr>
<tr>
<td>C. Self-efficacy: extent to which providers feel they are will be able to do what is expected</td>
</tr>
<tr>
<td>D. Skill Proficiency: possession of the skills necessary for implementation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. Characteristics of the Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Compatibility (contextual appropriateness, fit, congruence, match): extent to which the intervention fits with an organization’s mission, priorities, and values. <em>An intervention needs to embody some core values (Greenberg et al., 2003) and be prioritised long-term (Greenberg et al., 2003; Honess &amp; Hunter, 2014). There needs to be an understanding of how a program interacts with different environments (Gottfredson, Jones, &amp; Gore, 2002; Greenberg et al., 2003; Gregory, Henry, &amp; Schoeny, 2007).</em></td>
</tr>
<tr>
<td>B. Adaptability (program modification, reinvention): the extent to which the proposed program can be modified to fit provider preferences, organizational practices, and community needs, values, and cultural norms. <em>An intervention must also have the potential for differentiation (Greenberg, 2014).</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV. Factors Relevant to the Prevention Delivery System: Organizational Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. General Organizational Factors</td>
</tr>
<tr>
<td>1. Positive Work Climate: climate may be assessed by sampling employees’ views about morale, trust, collegiality, and methods of resolving disagreements</td>
</tr>
<tr>
<td>2. Organisational norms regarding change (a k a, openness to change, innovativeness, risk-taking): this refers to the collective reputation and norms held by an organization in relation to its willingness to try new approaches as opposed to maintaining the status quo. <em>School implementations work best where there is a whole school improvement culture and associated supportive leadership (Dulaney, 2012; Gottfredson et al., 2002; Lembke, Garman, Deno, &amp; Stecker, 2010; Gregory, Henry, &amp; Schoeny, 2007; Greenberg, 2014; Lendrum, Humphrey, Kalambouka, &amp; Wigelsworth, 2009).</em></td>
</tr>
<tr>
<td>3. Integration of new programming: this refers to the extent to which an organization can incorporate an innovation into its existing practices and routines. <em>Contextual fit must include resources needed (Todd, Campbell, Meyer, &amp; Horner, 2008) and specifically: suitable physical spaces (Lendrum et al., 2009) and enough time and/or dosage (Greenberg, 2005, 2014; Lendrum et al., 2009). Integration must also explicitly support generalisation by for example: links being made between Wave 1 and 2 interventions (Lendrum et al., 2009), promoting school-wide use (Greenberg, 2014) and coordination with the rest of the curriculum (Greenberg et al., 2003).</em></td>
</tr>
<tr>
<td>4. Shared vision (shared mission, consensus, commitment, staff buy-in): this refers to the extent to which organisational members are united regarding the value and purpose of the innovation. <em>Mutual support between facilitators is helpful (Gregory et al., 2007).</em></td>
</tr>
<tr>
<td><strong>B. Specific Practices and Processes</strong></td>
</tr>
<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>1. Shared decision-making (local input, community participation or involvement, local ownership, collaboration): the extent to which relevant parties (e.g., providers, administrators, researchers, and community members) collaborate in determining what will be implemented and how</td>
</tr>
<tr>
<td>2. Coordination with other agencies (partnerships, networking, inter-sector alliances, multidisciplinary linkages): the extent to which there is cooperation and collaboration among local agencies that can bring different perspectives, skills, and resources to bear on program implementation</td>
</tr>
<tr>
<td>3. Communication: effective mechanisms encouraging frequent and open communication</td>
</tr>
<tr>
<td>4. Formulation of tasks (workgroups, teams, formalization, internal functioning, effective human resource management): procedures that enhance strategic planning and contain clear roles and responsibilities relative to task accomplishments</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>C. Specific Staffing Considerations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Leadership: leadership is important in many respects, for example, in terms of setting priorities, establishing consensus, offering incentives, and managing the overall process of implementation</td>
</tr>
<tr>
<td>2. Program champion (internal advocate): an individual who is trusted and respected by staff and administrators, and who can rally and maintain support for the innovation, and negotiate solutions to problems that develop</td>
</tr>
<tr>
<td>3. Managerial/supervisory/administrative support: extent to which top management and immediate supervisors clearly support and encourage providers during implementation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>V. Factors Related to the Prevention Support System</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Training</strong>: approaches to insure provider proficiencies in the skills necessary to conduct the intervention and to enhance providers’ sense of self-efficacy. <em>(Identified as part of contextual fit by Todd et al. (2008)). It is important to be able to deliver a programme with fidelity (i.e. adherence), quality and appropriate differentiation (Greenberg, 2005, 2014; Knoche, Sheridan, Edwards, &amp; Osborn, 2010; Lembke et al., 2010) Implementation is affected by facilitators’ skills and experience (Lendrum et al., 2009), such that school staff need to feel it is sufficiently within their skill repertoire that the additional effort is worth it (and so it must give results too) (Todd et al., 2008). Implementation quality relates to the facilitator being prepared, creative and responsive to the pupils involved (Greenberg, 2014). Quality is possibly more important than dosage, with the worst scenario being high dosage of low quality (Greenberg, 2014). Pupils needs to have a positive experience, be involved in setting achievable targets and have suitable behaviours reinforced (Lendrum et al., 2009).</em>*</td>
</tr>
<tr>
<td><strong>B. Technical Assistance</strong>: this refers to the combination of resources offered to providers once implementation begins, and may include retraining in certain skills, training of new staff, emotional support, and mechanisms to promote local problem solving efforts. <em>Greenberg (2014) emphasises the importance of having support available: peer coaching/observation, regular opportunities for reflection, feedback and ongoing training. By contrast Langberg et al. (2011) suggest there is greatest potential for dissemination where specialist support is not required.</em></td>
</tr>
</tbody>
</table>

Greenberg et al. (2005) provide similar list of factors, differently presented as barriers as opposed to facilitating factors.

Given the inevitability of local adaptation, there is an argument for a programme to have built-in modification potential (Greenberg, 2014) and for local adaptation to be studied in its own right (Durlak & Dupré, 2008; Lendrum & Humphrey, 2012). Positive adaptations would preserve the crucial programme elements, integrate it fully into the local curriculum and add components to increase comprehensiveness (Greenberg, 2014).
Even this account is arguably simplistic. For example, Cantrell, Almasi, Carter and Rintamaa (2013) found that sense of efficacy can be more important than fidelity in producing outcomes, although Ross, Romer and Horner (2012) found that greater fidelity was associated with greater sense of efficacy. Giving a more dynamic perspective, Hanley and Darby (2007) explored the teacher journey during the implementation of a new mathematics curriculum where monthly training days were attended over a period of eight months. They found that initially teachers tended to attempt exact fidelity, alongside ensuring that they had lessons that would work in the classroom, in the sense of being acceptable to students. Over time, the teachers felt they increasingly understood the curriculum rationale and its underlying principles. This enabled them to take ownership and to engage in local customisation (here called adaptation), typically by changing the content vehicles (daily-life scenarios) to others containing the same mathematics; hence there was conscious adherence to programme principles (Hanley & Darby, 2007; Torrance, Hanley & Darby, 2007). Hanley and Darby (2007) suggested that the training over time supported the teachers’ trajectory or journey from fidelity to ownership and appropriate adaptation, this resonating with the importance of self-efficacy in achieving outcomes (Cantrell et al., 2013).

Having listed and/or described the kinds of implementation factors that will need to be considered in a full interpretation of findings, it is useful briefly to turn back to evaluation literature for tips on methodology.

For example, Jaycox et al. (2006) suggest the following for evaluation in schools:
- become familiar with the school environment and culture
- gain cooperation from all involved
- maintain contact throughout
- put time and planning into the consent process
- be sensitive to the school culture
- minimise the research workload (such as diary keeping) and
- ensure there is flexibility built into the implementation.

Lastly, Mertens (2005) reminds readers that the convenience sample is the most commonly used but least desirable in evaluation research, as it contains numerous
For example, Jaycox et al. (2006) suggest the following for evaluation in schools:

Any existing good practice for working on EF is in spaces where staff are exempted from the results pressure, for example in specialist provision.

Secondary schools must focus on exam results. Fitting in ‘extras’, such as interventions, is difficult.

Research access to secondary students will be difficult because of the focus on external exam results.

An intervention needs good theoretical anchoring and suggested mechanisms for generalisation. This focuses design and helps in implementation as training will more likely look at concept rather than manual detail.

Feedback seems to increase engagement by giving a focus to discussion: why some tasks take longer than others and/or generate more errors. This breaks down if tasks are too hard because students can no longer monitor effectively.

Secondary schools must focus on exam results. Fitting in ‘extras’, such as interventions, is difficult.

Risks need to be boundaried and yet successful EF work tends to be integrated into lessons.

EF interventions must be:
- restricted to non-risky Key Stage 3 year groups
- kept discrete from core lessons
- proven through properly resourced pilot work
- given currency in school, with protection and empowerment “from above”.

Intervention design factors identified in pilot work (Darby, 2013)

Some task accuracy is important to ensure some proper Shift.

Tasks need to be well presented:
- clear colours
- sufficient font size
- not too fiddly

Feedback seems to increase engagement by giving a focus to discussion: why some tasks take longer than others and/or generate more errors. This breaks down if tasks are too hard because students can no longer monitor effectively.

Tasks need to be fun and contain an element of novelty.

Difficulty can be changed through manipulating Inhibition requirements, rule complexity and skill blend needed.

Harder tasks can be reached faster if one task format is used more than once, but with different difficulty levels.

Targeting middle groups may make the most difference to results.

Socially mediated feedback will provide motivation and opportunities to develop reflection and metacognition, but facilitators must watch out for anxiety.

Self-management can be promoted through building in routine and giving a limited number of tasks to learn.

Tasks taken from research papers seem to work.

Where students are comfortable, discussion about the tasks seems to arise naturally between the learner and the facilitator (within-pair roles). Mistakes can then be a source of amusement and curiosity. Nevertheless, being the learner can create exposure. Facilitators like monitoring and timing their partners and also feel they are learning.

Students can self-manage working on Shift tasks and they enjoy working in pairs.

Tasks need to be fun and contain an element of novelty.

Socially mediated feedback will provide motivation and opportunities to develop reflection and metacognition, but facilitators must watch out for anxiety.

Self-management can be promoted through building in routine and giving a limited number of tasks to learn.

Black boxes from EF experts, red from school staff and blue from Year 7 students.
inherent threats to interpretation. Equally, a one group pre-test, post-test is a common evaluation method. Again interpretation is threatened: have students simply matured or received another intervention (not uncommon in schools) or have they got better on the test materials? Evaluation therefore typically requires mixed methods to support interpretation (Mertens, 2005) as already indicated above.

2.6 Literature summary
To recap briefly from Section 2.3, EF is an important cognitive skill in terms of its association with and predictive value for academic achievement and more general life outcomes. It is also vulnerable to damage and deficit. Teachers and other school staff have an intuitive understanding of EF through their experience of supporting it in the classroom, but would be wary of any intervention that detracted from examination-oriented studies. Although some evidence suggests that aspects of EF can be improved, the research area of EF intervention is still embryonic and yet to be proven in terms of classroom usability and day-to-day benefit. This essentially is the pragmatic rationale for the current research.

Section 2.4 provided a theoretical rationale to support EF intervention in adolescence. It suggested that more applied research into intervention is needed before conclusions regarding utility are drawn and that adolescent EF skills including Shift are still developing and potentially amenable to accelerated change. A modified model of EF was suggested that contains the three components (Miyake et al., 2000) within a Central Executive of limited capacity (Baddeley, 2012). In turn this indicated mechanisms for intervention. These were added to by a detailed consideration of the Shift-task paradigm that also allowed an account of EF development entailing component bootstrapping and increasing mutual coordination. Literature away from EF gave additional design suggestions, whilst research concerning EF measurement issues critiqued the Miyake et al. (2000) model and highlighted potential measurement difficulties in this study. The intention was that this written exploration reflected the researcher's journey of understanding; it will be drawn upon directly in the development sections of Chapter 4.

Finally in Section 2.5 there has been a brief consideration of implementation and evaluation research to highlight relevant issues in line with this study being an early-stage evaluation.
2.7 Aims of the research and the research questions

EF intervention is a developing research field with plenty of opportunity. The aim of this research was to contribute by building on a promising start with Shift intervention (Karbach & Kray, 2009) and taking forward this author's earlier ideas (Darby, 2013 a,b). Using her greater understanding of EF, this researcher aimed to develop an intervention that focuses on Shift skills, as they sit within EF as a whole and that acknowledges the practical difficulties of implementation within current typical secondary education settings. As Howard-Jones (2014) suggests, this is an ambitious but necessary step forward, but one that this author believes EPs are relatively well placed to take. Not only do they have the academic background to enable full engagement with neurocognitive literature, but they also work day-to-day in the settings that must ultimately host any wide-reaching EF interventions. It was not expected that this research would result in an ‘end-product’, but rather that it could:

- suggest theoretical underpinnings that could/should apply equally to any intervention
- add to the literature that will eventually determine whether or not EF intervention is a useful venture to pursue
- begin to create an evidence base for promoting EF skills in secondary schools, within the context of results-driven pressures and
- raise local awareness of the importance of EF, both through the research itself and by equipping this researcher with the knowledge to deliver training and to incorporate discussion of EF into day-to-day work as an EP.

It would hopefully make this contribution through addressing the following research questions:

1. How could a prototype Shift intervention with sound theoretical underpinnings be developed for young adolescents?
2. How might such a Shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?
3. To what extent could such a Shift intervention package produce anticipated and/or useful benefits?
Chapter 3  The methodology

3.1 Chapter outline and aims
This chapter firstly describes the researcher’s philosophical stance and how this is a good fit with both mixed methods and an evaluation study.

Secondly, it briefly recaps the research rationale and aims.

Thirdly it details the research design and indicates any modifications to original method intentions\(^1\). Sections are dedicated to participant recruitment, data collection methods and the approach to data analysis.

Finally there is a consideration of the major ethical issues raised by the research.

3.2 Philosophical stances: ontology, epistemology and axiology
This researcher would argue that over time her stance towards the nature of knowledge and methods that might be used to investigate reality and ascertain that knowledge has changed. In part this may be due to cultural influence (Kuhn & Park, 2005) acquired through experience in various education, work and life settings: physical sciences, social and health sciences, parenthood and teaching. Each would have privileged different ways of knowing and provided some challenge to those previously encountered (Hofer & Pintrich, 1997). Equally, some change in stance may be developmental and therefore have involved moves towards coordination and reconciliation of the subjective and objective (Kuhn, Cheney & Wienstock, 2000).

Regardless of the trajectory mechanisms, this author would now consider her epistemological position to be Critical Realism (Robson, 2011). This is congruent (necessarily) with her realist ontological position, that reality is a world of abstract things, at some level created in people’s minds, but that also exist independently and verifiably at some level (Healy & Perry, 2000). There is therefore a real-world to discover but it can only be explored imperfectly and with some uncertainty.

From this epistemological position, research can deal with complex social phenomena as open systems involving thinking, feeling people who act accordingly (Healy & Perry, 2000).

\(^1\) These were all made in response to the specific research context and in the main were changes in extent or size rather than significant moves away from the intended methods or timescales.
As reality exists, it arguably becomes possible to triangulate imperfect findings within mixed methods\textsuperscript{2}. Quantitative methods can be used in a critical way and this author would suggest this requires not only the ability to interpret within context but also a good technical knowledge to support some intuitive understanding. Equally, participants’ perceptions are deemed useful to study at least partly because they can provide a window onto the reality beyond those perceptions.

However, since open systems do not allow the causal inference found in more positivist laboratory experiments, Critical Realism instead looks for families of answers covering several contexts and different people (Healy & Perry, 2000). Interpretations allow for multiple values and beliefs (Mertens, 2005). Realistic judgements can be made regarding evaluation of effectiveness and how to use available evidence-bases in particular environments (Kelly, 2008).

Critical Realism would thus appear to be an appropriate stance for evaluation research of this kind. This author would also suggest it is the most likely overall stance to be able to rise to the challenge set by Howard-Jones (2008) and Goswami (2006): that work at the interface of neuroscience and education must be able to deal with the different discourses and integrate (and perhaps move between) the different epistemological stances (arguably relatively positivist\textsuperscript{3} and social constructivist respectively).

In terms of axiology, this researcher would like to believe that she holds some general values that have been applied to this research. Specifically that the study considered the best interests of the children involved, it privileged the voices of all participants as the experts in their particular situation and it avoided undue pressure for participants already leading busy and complex lives.

3.3 Research rationale and aims

As outlined in detail in Section 2.2, this research is part of a huge increased interest in EF created by evidence that EF has links with important outcomes

\textsuperscript{2} This is in contrast to Robson’s (2011) assertion that a defining characteristic of a mixed methods approach has been to have pragmatism as the philosophical underpinning: any research approach can be used so long as it allows the research questions to be answered.

\textsuperscript{3} This author would also suggest that even neuroscience findings cannot necessarily be interpreted conclusively, for example it is hard to distinguish brain activity seen alongside Switch performance as cause or effect, or even indeed whether the activity reflects for example cue interpretation or task-set activation.
throughout the lifespan including academic achievement and self-regulation (Röthlisberger et al., 2012) and that EF involves a skill set particularly vulnerable to decrement (Diamond, 2013). Teachers are aware of EF and support it daily in the classroom (Darby, 2013a). Whether or not EF can be positively influenced with meaningful benefit has yet to be established. The potential benefits of intervention are sufficient that early indications of limited reach should not force a premature curtailment of research effort. It is a research area that is contentious and evolving, but nevertheless one to which this researcher hopes to have contributed.

Evidence-based interventions are scarce (McCloskey, Perkins & Van Divner, 2009) and these primarily work indirectly, see Table A2.6. Direct intervention on a component skill has had some limited success for Working Memory in both experimental and educational settings (Holmes et al., 2009; Skelton, 2012). Laboratory-based work appears to indicate that adolescent Shift skills may also be amenable to direct intervention (Karbach & Kray, 2009). This study aimed to broaden the debate about the possibility of directly and usefully improving EF by developing an intervention for adolescents that focusses on Shift and can be delivered in school.

The position of EP provided a relatively tenable place from which to conduct this research, since the role constantly requires the application of research to practice and therefore the bridging of scientific and education research paradigms. It also allowed the consideration of secondary education priorities as encountered day-to-day, but set by local and national political agendas. This researcher believes that without sound evidence from research based in a typical secondary environment, the case for giving EF space within the curriculum will be difficult to make.

Hence the overall aim of this research was to make a modest contribution to the gap in knowledge: how can an EF intervention focussing on the Shift skill in adolescence be developed that would have meaningful benefits when delivered in a school? As such it was an early stage evaluation that was part general proof of concept and part exploration of sustainability and acceptability within a particular, but relatively typical secondary education setting.
3.4 Design of the study, research objectives and contributions to knowledge

As indicated in Section 2.5, this study was an early stage evaluation of whether the intervention developed was potentially worthy of further evaluation. This evaluation readiness requires that the intervention operates as intended, is relatively stable and seems to produce some benefits. These requirements fitted with the research questions and provided a natural structure to the current study through the associated evaluation steps:

- the intervention should be subjected to logical examination
- stakeholders in the implementation environment would verify whether or not the intervention operates as intended and with some smoothness and
- outcomes would be analysed for a whiff of positive results\(^4\) (Weiss, 1998).

In turn these steps helped to suggest the research objectives and outputs, as follows:

**Research Question 1:** How could a prototype shift intervention with sound theoretical underpinnings be developed for young adolescents?

**Objectives and outcomes:** The intention for this stage was to develop an intervention pre-prototype that might include:

- a cognitively-based model of how an intervention might work and likely areas of benefit, in the immediate vicinity of EF and perhaps beyond. The model would take into account EF structure and development and would consider the skill blend needed, especially EF skills, but also others such as visual, auditory and motor skills.

- a procedurally-based model that might build in a role for the Learning Hierarchy, social mediation, flow and performance feedback.

- a battery of tasks that had an indicated order of presentation, but with some room for flexibility bearing in mind Research Question 2. The majority of tasks were anticipated to be developed versions of those used previously (Darby, 2013b) see Table 2.3.

This theoretical development was to be monitored by experts in the field.

---

\(^4\) A whiff of positive result can be interpreted in the narrow sense of outcomes resulting from the specific intervention, but also within a wider research context. These ideas are pursued further under Research Question 3.
To this author’s knowledge, there was no existing intervention that specifically targets mental flexibility through the boosting of Shift skills. One that embodies a number of known relevant theoretical considerations was likely to be a contribution to new knowledge.

**Research Question 2:** How might such a Shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?

**Objectives and outcomes:** The intention for this stage was to take the pre-prototype and develop it into an intervention package that would work in the school environment, bearing in mind previous research and typical pressures (e.g. Darby, 2013a; Durlak & Dupré, 2008; Greenberg, 2014) and the need for flexibility especially during evaluation (Jaycox et al., 2006). The package would need to be attractive, structured in predictable ways, deliverable in time slots of as short as 15 minutes and manageable with limited training. Judgements regarding these aspects of a first version prototype were to be made by a multi-disciplinary group of relevant local professionals, or stakeholders.

The output from answering this research question was anticipated to be a prototype intervention package that a number of stakeholders would be comfortable with introducing into a school and for which implementation feedback would have been collected, see below. Again this author believes such an output would be novel.

**Research Question 3:** To what extent could such a Shift intervention package produce anticipated and/or useful benefits?

**Objectives and outcomes:** The intention was to trial the prototype package for about 6 weeks with a class of young adolescents in a mainstream secondary school. In line with previous findings (Darby, 2013a), trial sessions were anticipated to involve non-core curriculum time and specifically morning form-time. Performance data and participant views were to be gathered in an attempt to ascertain whether the package delivered what was expected, as outlined in the deliverable outcomes from Research Question 1 above and to gain formative information for the future. The realities of conducting evaluation research needed to be built into the associated methodology, such as the need to minimise busy participants’ research workload (Jaycox et al., 2006).
The intervention was to be run by a form tutor and/or teaching assistant. After training, they would take charge of the implementation immediately, or the researcher would model/support during the initial sessions.

It was anticipated there would be some difficulties in disentangling pure programme effects from specific implementation effects; this is inevitable in an early stage evaluation. Acknowledging and working with these difficulties was felt to be a better route than idealistically aiming for 100% fidelity for a specific intervention.

In more detail and looking firstly relatively narrowly at the specific intervention, this author believed (and still believes) that a useful response to Research Question 3 requires even a prototype intervention to produce positive results in less than perfect circumstances. Most simply, positive results might be embodied by improved performance on the EF function measures being used, if such improvements can be at least tentatively attributed to the intervention. Other positive results might include participant observations about how thinking skills have been usefully affected (perhaps indicating in turn that the intervention draws on the anticipated mechanisms of benefit) or relatively firm indications as to how the prototype could be improved to create measurable benefit in the future. It might be tempting to accept a period of smooth running as a positive result, but this requires cautious interpretation of the implementation as a whole. This author would suggest that orderly occupation of students for several minutes on several days is not in itself enough to allow one to conclude that the occupation was fruitful, although it may be necessary to avoid an intervention being abandoned in its early stages of use.

More broadly, identifying ‘a whiff of positive result’ from the study as a whole should pertain to the reporting of results that move one or more relevant research areas forward in some way. Most obviously, this could be a tentative evaluation of whether or not further research effort is worth expending in the area of EF intervention in adolescence, regardless of the fortunes of the specific intervention. As indicated in the rationale for this research, even this positive result would have huge potential (after considerable additional research), given the breadth of everyday experience in which EF is implicated. Other literature areas that might be impacted on include theoretical models of EF and its development, effective capture of data reflecting EF improvement and implementation science,
particularly a more dynamic description of implementer skills/knowledge and how these are best supported.

So, overall this study was a mixed methods exploratory evaluation. The Critical Realist perspective adopted by evaluation researchers suggests that purely quantitative methods would not provide insight and purely qualitative methods would not capture change in a sufficiently objective way. The mix varied between research questions and as shown in Figure 3.1 below. There was an emphasis on qualitative investigation of process in context and this reflects the proportion of research effort focussed on the pre-implementation stages. Figure 3.1 also attempts to illustrate how the research questions helped to define the research phases.

3.5 Sampling and participant recruitment and support

3.5.1 The expert participants

For the expert groups, the researcher recruited participants who would take part in both interviews. Eight EF experts were contacted for an intended group size of four or five. Just two responded who also had suitable availability. They had both been previously involved (Darby, 2013a).

The experts were treated as research participants who were taking part in the pre-implementation phase of a research study. As such their views would contribute to the answering of the first two research questions, in the same way that other participants’ views would contribute to answers for the second and third research questions. However, in line with the study being an early stage evaluation of a particular intervention, the role of the experts could be differently construed as contributing to product development. To acknowledge this possibility, the experts
**Figure 3.1: Research structure and method mix**

<table>
<thead>
<tr>
<th>Research Question (RQ)</th>
<th>Qualitative methods</th>
<th>Concurrent mixed methods</th>
</tr>
</thead>
</table>
| 1: How could a prototype Shift intervention with sound theoretical underpinnings be developed for young adolescents? | - Coherent theoretical structure:  
  **Data collection:** audio-recorded semi-structured expert group interview 1  
  **Data analysis:** inductive Thematic Analysis (Braun & Clarke, 2006) of full transcript, then member checking  
  **Suitable tasks with sufficient coverage:**  
  **Data collection:** audio-recorded semi-structured expert group interview 2  
  **Data analysis** inductive Thematic Analysis of full transcript, then member checking  
  **Participants:** practising Psychologists with postgraduate level qualifications and/or research experience in neuroscience. | - Whiff of positive results:  
  i) Quantitative pre-experimental one group pre-test post-test design ($O_1XO_2$) (Cohen, Manion & Morrison, 2007)  
  **Data collection:** pre- and post- performance on standardised NEPSY-II Inhibition task, providing a near Shift measure*  
  **Data analysis:** descriptive and inferential statistics  
  ii) Qualitative  
  **Data collection:** semi-structured individual interviews, as RQ 2 part two  
  **Data analysis:** Thematic Analysis as RQ2 part two, to include identification of possible far effects  
  **Participants:**  
  Quantitative: all Year 8 participants  
  Interviews: facilitators and eight Year 8 participants, as RQ2. |

<table>
<thead>
<tr>
<th>RQ2: How might such a Shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?</th>
<th>Qualitative methods</th>
<th></th>
</tr>
</thead>
</table>
| **Aim:** Produce a prototype intervention for evaluation in school and collect feedback from the implementation.                | - Tasks packaged to suit intervention environment:  
  **Data collection:** audio-recorded stakeholder focus group  
  **Data analysis:** inductive Thematic Analysis (Braun & Clarke, 2006) of full transcription, with member checking and inter-rater reliability checks (with other researcher familiar with Thematic Analysis)  
  **Intervention runs with some smoothness:**  
  **Data collection:** (i) semi-structured individual interviews, (ii) researcher diary  
  **Data analysis:** – (i) data driven, inductive Thematic Analysis of full transcript, (ii) inductive Content Analysis.  
  **Participants:**  
  Focus group: adult stakeholders for host secondary school.  
  Interviews: facilitators and eight Year 8 participants. |   |

| RQ3: To what extent could such a Shift intervention package produce anticipated and/or useful benefits? |   |
| **Aim:** Evaluate any measured or reported benefits.  
  **NB Time series data to be used to identify student interviewees** |   |

*The research proposal was originally accepted with retest standardised data being collected just for a small group identified from the class on the basis of the time series data. An amendment (May, 2014) allowed the repeat standardised measure to be taken for the whole class.*
were asked if they would like to be explicitly named within this research report. They both declined\textsuperscript{5}.

Experts were here defined as Psychologists who either have postgraduate qualifications in neuroscience and/or who have carried out postgraduate level research into aspects of EF. They were identified through the university via colleague and supervisor contacts or through publications and both were recruited by e-mail. Hence they constituted a convenience sample.

In addition, there was an agreement when this researcher’s fieldwork placement was negotiated that the placement supervisor would be an expert at the stakeholders’ focus group. As such the supervisor would have provided continuity of critical insight regarding EF whilst also being a stakeholder. At short notice she was unable to attend and was not replaced.

\textbf{3.5.2 School-based participants}

Using knowledge within her placement local authority’s educational psychology service, the researcher recruited participants in a maintained secondary school with a reputation for openness to new and experimental ventures. Again this was convenience sampling and not ideal, despite its prevalence in this kind of research (Mertens, 2005). The researcher met with the school’s Special Educational Needs Coordinator (SENCo) to negotiate optimum access to students, whilst respecting existing school arrangements and priorities. These precluded the hosting of the research in a Year 7 form. This year group is targeted for literacy interventions during form-time and so the remaining form composition would have compromised the cross-section of participants.

The school SENCo approached likely Year 8 \textbf{form tutors} and shared with them information supplied by the researcher. The researcher then met with the most positive respondent who agreed to host and co-manage the research in his form, subject to being happy with the intervention logistics detail. He was shown materials from the pilot (Darby, 2013b) to get a sense of the kinds of skills being targeted and likely intervention activities. This Year 8 form tutor was a science teacher with eight years’ experience.

\textsuperscript{5} It would seem appropriate to consult with them again, were the intervention to reach later stages of product evaluation. Equally, at this stage, it would be appropriate to consult with the school staff whose views shaped the prototype appearance, as well as the researchers whose tasks were drawn upon and developed.
The SENCo also approached two **teaching assistants** with a view to them running the intervention between them, with support from the researcher and the form tutor. Their initial reactions were both positive. The researcher similarly met with them to introduce the basic principles and some of the likely tasks. Three months before the implementation started, one teaching assistant asked to withdraw from the research, but the other expressed her interest in taking the main responsibility. This teaching assistant has had more than 15 years’ experience in the role, including taking cover lessons when necessary.

The intention was that the facilitator(s) would receive some training from the researcher before the start of the intervention. The researcher would then co-facilitate initial sessions with the Year 8 form until the teaching assistant felt confident to run sessions herself. In practice, having seen the amended materials used briefly, the teaching assistant felt she needed no further training or modelling and she ran the initial sessions independently. However, as her other responsibilities were not reduced as expected, during later weeks the researcher ran the intervention once each week instead of carrying out an observation. In the circumstances this seemed reasonable and a better option than having to find another facilitator at short notice.

For **stakeholder focus group**, the intention was that a variety of four or five relevant adults would contribute, mostly from the host school but also the local authority. In the event, the attendees were all from the participating school: the form tutor hosting the intervention, a teaching assistant who would facilitate it and the school SENCo. As indicated above, all had previously met with the researcher to discuss what the research was about. They had also received a short written briefing and the consent form, see Appendix 3.1.

The young **adolescent participants** were recruited from the Year 8 form indicated above (23 students). The research was introduced to them by the researcher during a form-time session. One concern was that having a whole form as the unit of study would put pressure on the students to participate\(^6\) (i.e. to not be left out). This issue was addressed explicitly by the researcher during the introduction. Students were also given a written invitation\(^7\) containing background information

---

\(^6\) See ethics section 3.8.

\(^7\) This was amended from the original format, see Appendix 3.1.
and a consent form (see Appendix 3.1), the latter to be returned within two weeks if they wanted to take part. In the intervening time, an information evening was held for students and their parents/carers to find out more about the research before making a decision regarding participation; nobody attended. Timescales and planning allowed for generous recruitment time, as suggested by Jaycox et al. (2006).

22 students returned their consent forms and took part in the intervention implementation. They were less representative of a typical Year 8 class than anticipated: the form tutor was perceived to manage poorer performing students well and his form therefore had a greater proportion of students who were seen to struggle and particularly boys described as disorganised and vulnerable. Demographically, the participating students were split as follows: 11 girls and 11 boys; 10 in the age group 11:00 – 12:11 years and 12 in the age group >13:00 years at the time of the baseline data collection; 6 and 16 were in these respective age groups at the time of the retest data collection.

On the basis of time series data, see below, eight of the students were selected to be asked if they would feedback through individual interview, with the hope that six would agree. All eight wanted to take part, but they expressed a preference for giving feedback in same-sex groups rather than individually. Accepting all eight on their terms seemed an ethically sound decision.

In line with the need to be flexible (Jaycox et al., 2006), there was a contingency plan that if the full class intervention had to be abandoned, due to session or participant attrition, then a small group of six or more students would be convened to continue the intervention away from the whole class and to feedback through individual interview.

Approximately 4 weeks after the final data were collected, the student participants were provided with personalised thank you letters, to acknowledge their participation and to inform them that they would receive further feedback. An anonymised example is shown in Appendix 4.9. After a further four weeks, the researcher fed back an overview of results to all school participants during morning form-time. They were also provided with a brief summary to take away, see Appendix 4.9.
3.6 Methods
This section provides some detail on the methods to be used. Again, Figure 3.1 pertains, whilst a detailed research schedule can be found in Appendix 3.2, and a diagrammatic summary of the intervention phases and sessions is shown below in Figure 3.2.

3.6.1 Mixed methods
There is an endless variety within mixed methods in terms of relative weightings of quantitative versus qualitative in both data collection and/or interpretation and in terms of the extent to which the data types are integrated (Teddlie & Tashakkori, 2006).

Nevertheless, attempts have been made to at least provide dimensions of difference that generate logical paradigm combinations (Leech & Onwuegbuzie, 2007). Leech and Onwuegbuzie (2007) suggest the dimensions: full versus partial, time and emphasis. This study does not fit neatly within any of their generated paradigms. Rather it could be seen as a sequentially qualitative (for Research Questions 1 and 2) and then a fully mixed concurrent with equal status design (for Research Question 3) and therefore perhaps really a quasi-mixed methods design (Teddlie & Tashakkori, 2006).

The brief outline in Figure 3.1 indicates how different strands of data gathering were to be integrated to address a particular research question, even though they may have been gathered sequentially within the development and evaluation process.

Specifically, for the first research question, themes emerging from the first expert group interview would guide the content prepared for the second and themes from the second would help to shape the pre-prototype and then a first version package. This would then be presented at the stakeholder focus group. Stakeholders’ views would critically inform the prototype to be implemented and start to address the second research question. Hence member checking was vital to the research/development process. Diary entries and later interviews were intended to pick up unanticipated difficulties from several perspectives: the researcher, the administrator and the students. These insights would complete the input into Research Question 2.
Figure 3.2: A diagrammatic summary of the implementation

<table>
<thead>
<tr>
<th>Week’s activity</th>
<th>Baseline data: NEPSY-II*</th>
<th>Baseline data: NEPSY-II</th>
<th>Half term holiday</th>
<th>Intervention week 1</th>
<th>Intervention week 2</th>
<th>Intervention week 3</th>
<th>Intervention week 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sessions</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>M T W Th F</td>
<td>M T W Th F</td>
<td>M T W Th F</td>
<td>M T W Th F</td>
</tr>
<tr>
<td>Comments</td>
<td>Second class introduction by researcher.</td>
<td></td>
<td>Wednesday observation requested to be session facilitation.</td>
<td>Sessions cancelled (including observation) – due to timetable changes.</td>
<td>Wednesday observation requested to be session facilitation.</td>
<td>Observation cancelled with session – year group outing. Two sessions in Friday PSHE.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week’s activity</th>
<th>Intervention week 5</th>
<th>Intervention week 6</th>
<th>Holiday</th>
<th>Holiday</th>
<th>Follow up data: NEPSY-II and interviews</th>
<th>Follow up data: NEPSY-II and interviews</th>
<th>Follow up data: NEPSY-II and interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sessions</td>
<td>M T W Th F</td>
<td>M T W Th F</td>
<td>n/a</td>
<td>n/a</td>
<td>M T W Th F</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Comments</td>
<td>Observation moved to fit around session cancellation (caused by strike). Used to co-facilitate to boost morale.</td>
<td>Tuesday and Wednesday observations requested to be session facilitations.</td>
<td></td>
<td></td>
<td>Session to collect final time series data. Follow up data collection started Thursday.</td>
<td></td>
<td>Monday to Wednesday used to finish follow up data collection.</td>
</tr>
</tbody>
</table>


Shaded blocks indicate intervention sessions. 15 sessions were delivered, each of approximately 15 minutes. The sixteenth session was exclusively used to collect final time series data.
For the third research question to be answered, the numeric performance findings would need to be interpreted in light of the qualitative context, as would be expected within Critical Realism and evaluation and implementation research. Some descriptive and inferential statistics were generated and then integrated with contextual information, specifically students’ and facilitators’ perceptions of benefits.

3.6.2 Approach to development of Shift activities
Although the majority of tasks were likely to be developed versions of those used in the earlier pilot work\(^8\) (Darby, 2013b), see Table 2.3, the researcher planned to revisit theoretical conceptions of Shift and EF, so that activities could be systematically arranged within an intervention, rather than being a random group of Shift tasks as previously. In addition, the package would be influenced by the limited access to students, short time slots available in morning form-time, as well as design suggestions emerging from additional literature areas. Further detail follows in Chapter 4, Sections 4.2 and 4.3, the results from the theoretical and practical development phases.

3.6.3 Qualitative data collection and analysis
As indicated above, qualitative data were collected at all stages of the research and the study design mostly required earlier data to be analysed before the next research step could be commenced. Again refer to Figure 3.1.

3.6.3.1 Group interviews and focus groups
In the absence of a sensitive topic and in the interests of time efficiency, group techniques were chosen for gaining reactions to both the theoretical and practical developments of this research. The decision then was between group interview or focus group.

For the first research question, the original intention was to hold two expert semi-structured group interviews where the questions posed represented end-points to be verified. In the event, what was actually needed was formative discussion to allow progress. This is what took place: focus groups where the researcher had

---

\(^8\) In turn these had primarily been generated using an established approach: identifying tasks already used in the assessment of Shift (Röthlisberger & Neuenschwander, 2012), many through the Yeniad et al. (2013) meta-analysis paper on Shift skill associations.
equal voice. Given the circumstances this seems an appropriate change to original methodology.

The groups were held at times and locations convenient to the experts, as agreed through e-mail correspondence. The researcher sent development ideas to them by email about four days before each session.

The stakeholder discussion, an initial reaction to practical development work, also took the form of a focus group. Attendees requested that no information should be sent beforehand; a first version of the intervention prototype was taken to the group, so that stakeholders could interact with it, including role play as student participants. The focus group was held in school, at attendees’ convenience.

Semi-structured interviews were used to collect feedback. These interviews were held in school at participants' convenience, during the first two school weeks after the end of the intervention and to minimise disruption to pupils’ learning. They covered implementation issues that would feed into Research Question 2 and then they explored tentative/formative suggestions regarding far transfer effects, including specific curriculum benefits, that might inform the third research question.

The schedules used for all interviews and focus groups can be found in Appendix 3.3. A different schedule was created for each of: the first expert group, the second expert group, the stakeholder group, Year 8 participant feedback and implementer feedback.

During each interview and focus group basic good practice was to be attempted: an informal atmosphere and surroundings, a short phase of rapport building and clarity over discussion purpose, participant confidentiality and discussion structure (Wengraf, 2001). To minimise school participants’ research workload (Jaycox, et al., 2006) each school-based discussion was scheduled for a maximum of thirty minutes, with the exception of the stakeholder focus group.

All interview and focus group discussions were fully transcribed. The original intention was for expert interviews to be analysed using Content Analysis (Cresswell, 2008), whilst all other transcripts were to be analysed in somewhat greater depth using Braun and Clarke’s (2006) six phase model of Thematic Analysis. Both methods would allow the identification and description of themes which could then be related back to the research questions. Since this researcher
was familiar with Thematic Analysis, it seemed appropriate to give all transcripts equal treatment; all were analysed using Thematic Analysis.

Looking in more detail at the Thematic Analysis method, following Braun and Clarke (2006) a number of analysis decisions were made. Firstly, an initial coding was to be given to any excerpt that contributed relevant information. Secondly, the analysis was to be a thematic description of the entire data set. Thirdly, the analysis was to be inductive despite the guiding questions so that unanticipated themes could emerge. Finally, the themes were to be semantic i.e. the data taken at face value, although some later critical interpretation could allow for the identification of potential latent themes.

The six suggested phases (Braun & Clarke, 2006) were to be addressed specifically as follows:

Phase 1. The transcripts were to be read through alongside listening to the recordings, so that corrections could be made. Each transcript was to be read again and some paraphrasing written in to the left-hand margin, as this researcher has found this to be helpful in terms of starting to gather meaning from the text.

Phase 2. An initial code was to be given to interesting pieces of data and written into the right-hand margin of the transcripts. An example of a transcript page thus annotated can be found in Appendix 4.4.

Phase 3. The initial codes were to be written out, one per mini post-it, and then arranged into themes to create initial thematic maps. Figure A4.5 in Appendix 4.4 is a scanned image of an exemplar.

Phase 4. All of the extracts relating to each theme were to be collated and reviewed. Also the initial codes were to be reviewed and as a consequence somewhat modified. Samples of the excerpts per final code are given in Table A4.5 in Appendix 4.6. This phase would thus include a tidying up and revisiting of phases 2 and 3, such that intermediate thematic maps might sometimes be necessary, for example the scanned image in Figure A4.6, Appendix 4.5. Then final thematic maps could be generated, see Chapter 4, Results, where rectangles and ovals indicate main themes and sub-themes respectively.

Phase 5. Basic descriptions were to be written for each theme, including its sub-themes.
Phase 6. This stage was to combine the descriptions from phase 5 with a final selection of extracts to create a section of the results that would allow relevant research questions to be addressed. However, specifically for the third research question, this analysis was to provide much of the contextual backdrop against which the quantitative findings could be interpreted.

3.6.3.2 Observations and diaries

The original intention was for observational data to be collected during the implementation phase for a number of reasons. The data would give the researcher direct access to what was unfolding, without recourse to others’ mediating descriptions (Cohen et al., 2007). Equally they would give a contextual backdrop against which to interpret others’ descriptions, as they would be given in this research in later feedback interviews (Cohen et al., 2007). This is in line with a Critical Realist viewpoint where a number of realities may be constructed. More specifically to evaluation, they would give the researcher a sense of the prototype package usability through seeing how the participants were using it (Dumas & Redish, 1999).

However, as indicated in Figure 3.2, observations were precluded because of session cancellations and the need to run/co-run sessions. Session cancellations also precluded some early opportunities to gain feedback for any urgently needed intervention adjustments.

This researcher kept a general reflective research diary containing dated unstructured notes on for example, research difficulties, unanticipated events, implementation observations, informal participant feedback and additional issues that might feed into the write-up. It would give a temporal dimension to later reflections that might otherwise be lost (Lewis, Sligo, & Massey, 2005) and would be explicitly included in the write-up where/if it offered a complementary key perspective. In practice, the diary provided crucial information about the implementation in lieu of intended observational data.

The programme implementers were also encouraged to keep diaries. They were given small blank books and a list of prompts relevant to usability and engagement and informed by evaluation and implementation research (Durlak & Dupré, 2008), see Appendix 3.4. The intention was that this would encourage reflection and this would in turn enhance the quality and quantity of information gathered in the
feedback interviews (Lewis, et al., 2005). However, in line with the need to minimise the research workload (Jaycox et al., 2006), this record-keeping was not indicated to be central to the research effort and the suggestion was that a few minutes spent each day would suffice. In practice, participating school staff did not use their research diaries.

The researcher’s diary was subjected to a basic Content Analysis to produce themes (Cresswell, 2008).

3.6.4 Quantitative data collection and analysis

Quantitative data were collected during the implementation phase of the research, as previously indicated in Figure 3.1.

Originally, part of the feedback data collected by students as a way of promoting reflection on progress was also to be used as an extreme near measure of change that could identify a small group for closer monitoring. Figure 3.3 below presents a sample from the intervention booklet including the table designed to collect this time series data: basic measures of the number of errors and time taken for the same particular task on successive weeks⁹.

**Figure 3.3: Time series data tables from student booklet**

<table>
<thead>
<tr>
<th>Date</th>
<th>How long?</th>
<th>How many errors?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday 27/02/14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday 06/03/14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thursday 13/03/14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

_testing the tasks:_

You need: Test Cards ○ and □.

Record what happened in the table below.

⁹ Data were not needed from every week, but collection allowed a weekly routine.
The data were superseded as a near effect measure for the form as a whole. A research amendment was granted allowing the collection of standardised data (NEPSY-II Inhibition subtest) for all participants. It seemed important to use a standardised procedure to collect some outcome information, so that comparable pre-test/post-test data sets could be produced.

The first and last sets of the time series data had already been used to identify the four students who appeared to have made the least and most progress; they were invited to volunteer for feedback interviews. Their standardised data would suggest they actually represented a cross-section of change and this would appear to support the belief that the time series data were unreliable\(^\text{10}\).

The standardised baseline data (NEPSY-II subtest Inhibition) were collected during form-times between ten and 21 days before the intervention commenced. Follow up data were collected again during form-times at between 22 and 35 days after the main intervention finished, see Figure 3.2. Data were collected in a quiet room.

The Inhibition subtest is designed to assess the “ability to inhibit automatic responses in favour of novel responses and the ability to switch between response types” (Korkman, Kirk, & Kemp, 2007b, pg. 71). It asks participants to respond to:
- black or white squares or circles. First they name the shapes, then they name the other shape (i.e. say square for circle and vice-versa) and finally they give a colour contingent response (the correct shape if black and the other shape if white).
- black or white arrows pointing up or down. First participants give the arrow direction, then they give the opposite direction and finally they give a colour contingent response (the correct direction if black and the other direction if white).

Each main task thus has a Naming component, an Inhibition-plus-Naming component and a Shift-plus- Inhibition-plus-Naming component. By combining the corresponding components from each main task, the subtest yields three main

---

\(^{10}\) The researcher noticed on several occasions that errors were not picked up by either member of a pair and/or there was disagreement about the number of errors. Also, the stop clocks provided required firm button pressing: it was not clear that the times recorded were those when a task was completed rather than when the clock was finally stopped.
scores: Naming, Inhibition and Shift. Table 3.1 summarises all score types generated by the NEPSY-II Inhibition subtest.

**Table 3.1: Scores generated by the NEPSY-II Inhibition subtest**

<table>
<thead>
<tr>
<th>Score Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming combined scaled score</td>
<td>This provides a measure of the main non-EF skill required to engage with the subtest.</td>
</tr>
<tr>
<td>Inhibition combined scaled score</td>
<td>This provides a measure of the ability to inhibit a prepotent response.</td>
</tr>
<tr>
<td>Switch combined scaled score</td>
<td>This provides a measure of cognitive flexibility and also overall EF capacity.</td>
</tr>
</tbody>
</table>

Combined scaled scores give an overall skill level that is made up of speed and accuracy. Sub-scores for just speed (scaled scores for time taken) or just accuracy (percentile grouping for errors made) are also available for each of the three skill areas: Naming, Inhibition and Switch. These allow performance to be categorised as: slow and accurate, fast and accurate, slow and inaccurate or fast and inaccurate. Speed and accuracy are combined into combined scaled scores using tables provided in the manual.

Test-retest data are supplied for the speed scores:

<table>
<thead>
<tr>
<th>Score Type</th>
<th>Increase in mean scaled score for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naming:</td>
<td>11:00-12:11 years</td>
</tr>
<tr>
<td>Inhibition:</td>
<td>1.1</td>
</tr>
<tr>
<td>Switch:</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**Total Error scaled score.** This provides a measure of error level over the whole subtest. Test-retest data are supplied:

<table>
<thead>
<tr>
<th>Score Type</th>
<th>Increase in mean scaled score for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Error</td>
<td>11:00-12:11 years</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Contrast Naming-Inhibition scaled score.** This gives a more direct measure of Inhibition.

**Contrast Inhibition-Switch scaled score.** This gives a purer measure of cognitive flexibility, over and above Inhibition, so long as it appears that a child has not reached cognitive overload.

The number of participants in the NEPSY-II age groups were follows:

<table>
<thead>
<tr>
<th>Before intervention</th>
<th>After intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00-12:11 years</td>
<td>10</td>
</tr>
<tr>
<td>13:00-16:11 years</td>
<td>12</td>
</tr>
<tr>
<td>11:00-12:11 years</td>
<td>6</td>
</tr>
<tr>
<td>13:00-16:11 years</td>
<td>16</td>
</tr>
</tbody>
</table>

Test-retest data are taken from Clinical and Interpretative Manual for NEPSY-II (Korkman, Kirk & Kemp, 2007).

To produce a conservative estimate of any improvement, an attempt was made to remove practice effects\(^\text{11}\) from the retest standardised data. Examples are given in Figure A4.13, in Appendix 4.10.

---

\(^{11}\) Some participants needed the retest practice provided to remember to not use colour contingency for earlier items. This indicated a practice effect although it was not necessarily helpful.
For retest combined scaled scores (Naming, Inhibition and Switch), this was done by correcting both the time and the error contributory scores in two separate steps. For the time, the documented mean retest increase was removed from each student’s retest time scaled score according to their age group at the time of retest, see Table 3.1 above. For errors, each student was moved down one grouping in their retest error banding. This was done on the basis that it was a correction of suitable size when compared with the mean retest improvement for Total Error, see Table A4.8 in Appendix 4.10 for supporting calculations.

For retest Total Error scaled scores, correction was achieved by subtracting the documented mean retest scaled score increase from each student’s retest scaled score according to their age group at the time of retest.

Analysis of quantitative data was achieved by creating basic descriptive statistics, diagrammatic representations and non-parametric inferential statistics, all using the corrected retest data (except where explicitly indicated).

### 3.7 Critique of methods and ideology

Taking pragmatic decisions about data collection and using mixed methods per se could be seen as being in line with an ‘anything goes’ philosophy, namely pragmatism (Robson, 2011). Nevertheless, this researcher would argue that her intention to recognise and triangulate differing perspectives i.e. versions of the truth and to evaluate her implementation with regard to context, both support Critical Realism as the appropriate epistemology.

#### 3.7.1 Qualitative methods

Previous experience of running expert groups with these known participants (Darby, 2013a) suggested that advice and discussion were likely to be constructive and without additional agenda, whereas the stakeholder group and feedback interviews were more of an unknown.

Since interviews have an emphasis on directed facilitator-responder interactions, where specific questions need to be answered they could be the right option (Boddy, 2005) for group discussion. This was the logic underlying the plan to use interviews with the expert groups. Making the interviews semi-structured would

---

12 Calculations prior to the study had suggested a minimum sample size of 25 for the use of inferential statistics, however post hoc power calculations reported in Chapter 4 suggest that 22 participants was sufficient.
promote depth, as the researcher would also be able to be responsive in the moment to what was offered (Cohen, Mannion & Morrison, 2007).

Similarly regarding analysis, Content Analysis (2008) initially seemed sufficient for an inductive analysis of the expert group transcripts, since latent themes were not expected. Rather emerging themes would likely ensure the specific questions were addressed. The decision to use Thematic Analysis for all transcripts was in part pragmatic, based on recent analysis experience.

Previous work had also suggested that school staff might use the opportunity to express wider opinion and that it would be important to provide space for this (Darby, 2013a). Hence a focus group was used to engage stakeholders: it would promote interaction between participants, including the facilitator, who only intervenes to keep the discussion on the area of interest (Boddy, 2005) and would therefore allow differing viewpoints to be privileged as befits an evaluation of this kind (Robson, 2011). The use of a focus group also fits with a relatively inductive analysis.

Feedback was however sought through interview. For discussion with individual facilitators clearly this was the only option. For discussions with pupils, interviews seemed more appropriate than focus groups as they would likely place less onus on participants to maintain a discussion and to demonstrate discursive skills.

Thematic Analysis seemed a suitably flexible approach for all feedback analyses and the stakeholder focus group. It would allow for the identification of all semantic themes relevant to a straightforward Critical Realist evaluation, but it would also give the freedom to look at multiple layers of interpretation by referring to potential/latent themes that acknowledge a degree of constructionism (Braun & Clarke, 2006).

Some alternative analysis methods were considered:
- phenomenological techniques – here themes are expected to reflect how people make meaning of their lived experience
- discourse analysis – this looks at how language is used to accomplish projects
- grounded theory techniques.

The first two were rejected as having too heavy an emphasis on interpretation. However, Starks & Trinidad (2007) recommend grounded theory for researchers and practitioners who seek exploratory models upon which to design interventions,
so arguably this approach merited further consideration. In the end, as indicated above the decision to use Thematic Analysis was in part pragmatic, this researcher having had more recent experience in this approach. In addition, Thematic Analysis has been described as a technique that is accessible to students and although it lacks allegiance to philosophy, also as a method with potential substance so long as findings are related back to previous research (Coolican, 2013).

3.7.2 Quantitative methods
As outlined in section 2.4.2.2, EF measures are vulnerable to test-retest score improvement, either from a simple practice effect or because less EF is actually required second time around.

Two potential solutions were considered for this issue. The first was to use two different measures before and after intervention. This was rejected because differences in the skill blends needed may falsely create apparent improvements in EF performance (Miyake & Friedman, 2012). The solution adopted was to make score adjustments at least in line with published test-retest reliability data and as outlined above.

The specific measure used, the NEPSY-II Inhibition subtest, was chosen for several reasons. There is published test-retest reliability data, that should allow the intended score adjustments to be made, hopefully then allowing true improvements to show. There are published UK norms for 5 to 16 year olds, allowing British adolescents to be given comparable standardised scores. By having a Naming score, the subtest takes account of the main non-executive skill required and attempts can perhaps then be made to attribute other score changes to EF development. Finally, the subtest can be administered in 5 to 10 minutes per participant. This made it realistic to collect base-line and retest data.

Alternative standardised measures were considered, for example subtests from the Behavioural Assessment of the Dysexecutive Syndrome in Children (BADS-C) (Emslie, Wilson, Burden, Nimmo-Smith & Wilson, 2003). Arguably some of the measures would have provided greater real-life validity as they require problem solving and monitoring and so would also have given an indication of less-near transfer. Also, they don’t follow the Shift-task paradigm whereas the NEPSY-II Inhibition subtest does, albeit with greater response inhibition requirement created
through heightened task conflict. However, administration of the BADS-C subtests is more time-consuming and an additional IQ measure is needed to create standardised scaled scores. The NEPSY-II subtest represented a pragmatic solution.

There is an argument that EF measures should be at the level of latent variable because of task impurity issues (Willoughby et al., 2014). As indicated above, the NEPSY-II Inhibition subtest takes some account of this through having a specific Naming skill measure, against which Inhibition and Shift skills are compared. It should therefore capture improvements in both executive and relevant non-executive skills. Equally, given the EF model and development mechanisms suggested, task impurity within the EF area is not an issue: near effects would be expected on all three core components. A numerically quantifiable whiff of positive results (a whiff in its narrowest sense) could be for any or all three core component skills. That an apparent increase in Shift skill (on a contaminated task) might actually be due to an increase in all core skills doesn’t matter, except in any temptation to over-interpret results in pure skill terms.

Ideally more measures would have been used, but with the documented limited access to student time this was not a possibility.

Equally any apparent score improvements would be considered more robust if supported by later maintained improvements. Such follow up measurements did not fit the school agenda and so were not planned into the research design and perhaps are not essential for a whiff of positive result.

3.8 Ethics
The research was planned to take into account the following ethical guidelines: the British Psychological Society’s Code of Ethics (2006), the Health and Care Professions Council’s Standards of Conduct Performance and Ethics (2012) and the University of Manchester Institute of Education’s Ethical Practice Policy and Guidance (2013). Therefore the following principles were intentionally built-in: the right to dignity, equality, privacy, confidentiality and the avoidance of harm; informed consent to participate; voluntary participation; the right to withdraw at any time; the research to be conducted with integrity and with high standards of professionalism.
Ethical considerations that may have been particular to this research include possible anxiety generated in students by EF measures and by the feedback inherent in the intervention. Also students might have experienced peer pressure due to the attempted recruitment of a whole class of students. In this scenario it was perhaps harder for pupil participants to feel that they were volunteers who could withdraw at any time. In practice, having a whole form as the unit of study did not appear to have created pressure to participate. The one student who did not take part took up the role of class helper, both supporting the form tutor to complete day-to-day administration and supporting the teaching assistant to ensure participating students had the materials they needed.

One unanticipated ethical issue regarding students, was the form tutor applying pressure on participating students to ‘get on’ with the intervention tasks, as though they were in lesson time. This researcher responded by trying to tactfully remind the form tutor that the students were to self-manage the intervention. A second unanticipated ethical issue was a particular reaction to the intervention tasks. One girl said the way they messed with her thinking was uncomfortable and made her feel less confident. This was addressed through regular debriefing with the researcher and reassurance that she need not continue. Thus alerted, the researcher made specific efforts to talk to each participant regularly to ensure they were happy to continue. Running the intervention provided the necessary opportunities.

For the adults involved, anxiety might have been generated through having research requirements alongside their usual workload. In practice this applied mainly to the teaching assistant; she reported the workload issue, but also that in the short term she was happy to carry it.

Measures taken to minimise these ethical risks are outlined in Appendix 3.5 and they influenced both the intervention design and data collection methods. For example, the intervention was designed to self-run as far as possible, thus minimising pressure on the facilitators but also allowing student participants to have their usual social catch up in form-time alongside engaging with the research tasks.

Research approval was received on 02/08/13 and approval for the amendment was received on 23/05/14. Details for both are in Appendix 3.5.
Chapter 4: Results

4.1 Chapter outline and aims
The chapter will report the study results in their chronological order: the theoretical development, the development of a prototype intervention and finally the implementation evaluation. A summary of results is not included in this chapter, but instead prefaces each of three discussion sections, where the information will be split somewhat differently, to better fit the research questions.

4.2 The theoretical development
The theoretical exploration and development undertaken by this researcher with the support of the EF experts who attended the group interviews, led to the creation of a task matrix (pre-prototype) that could underpin a prototype intervention. The associated process and outcomes are the grist of this section, rather than a lengthy recap of the literature: the top part of Figure 3.1 is pertinent. In Chapter 4, the corresponding results summary is more integrative.

4.2.1 Early theoretical exploration before the first expert group
The exploration of literature areas typically summarised in EF intervention accounts (Section 2.3) put this researcher in the position of having a recognised model of EF to work with (Miyake et al., 2000) and a pragmatic rationale for attempting intervention. Specifically that EF is associated with daily functioning throughout the life span and including academic performance in school, that some groups are more vulnerable to poorer EF and that EF intervention research is a relatively undeveloped area with mixed/limited useful results to date. For Shift specifically, training appears to have been successful in the laboratory with both children and adults (Karbach & Kray, 2009). Additionally, teaching staff seem to have an informal understanding of EF and how to support it, based on experience. Whilst endorsing the principle of EF intervention, they would be wary of detracting from measured school results.

Earlier work (Darby, 2013a,b) had provided guidance on a more robust approach to intervention development, for example being explicit about Shift difficulty and non-executive skill requirements. More specifically, the pilot work in school had shown how participants might interact with tasks. They had spent time discussing
why they found themselves making mistakes on activities that appeared superficially simple.

With these knowledge bases, this researcher was better placed to start developing a logically defensible intervention. It needed a firm theoretical rationale. A number of steps were taken in the attempt to create one. Firstly it seemed important to remove lingering doubts from this researcher’s mind regarding the validity of EF intervention. Then literature critical of the Miyake et al. (2000) model was evaluated, the nature of the Shift skill was further investigated and the Miyake et al. (2000) model was reconciled with other models of cognitive control. These steps allowed theoretical mechanisms for change to be suggested.

The first two of these were tackled through private exploration and resolution, whilst the others fed into the first expert group interview. Progress on each is described in turn below.

4.2.1.1 The validity of EF intervention

This issue was approached through asking if general cognitive functions are amenable to intervention. The answer was sought through exploration of two literature areas.

The first was the debate addressing the application of neuroscience to education. This researcher became more aware of a general need for applied research, especially that which rises to the challenge of bridging the neuroscience-education gap in discourse and epistemology. It also convinced her that Educational Psychologists are well-placed to span the bridge and along the way to caution schools against simplistic misuses of neuroscience. In addition, this researcher concluded that EF intervention research is at an early and difficult stage where literature is accumulating, the documented useful effects for children (and adults) are modest, but the field is too young to abandon.

The second literature area was EF development both in terms of cognition and brain substrate. Cognitive development research suggested that EF including Shift develops through adolescence and into early adulthood. Neuroscience findings indicated that prefrontal cortex is undergoing important structural changes in early adolescence that appear to enhance environmental responsiveness, that in turn could perhaps be capitalised on through intervention. This possibility was not undermined by the documented high heritability of EF, as a change in shared
experience can boost skills for all. However, remediating extreme poor EF in children who have experienced severe early trauma may be exceptionally difficult. Overall, this researcher felt that the literature was supportive of the notion that general cognitive functions are theoretically amenable to intervention.

4.2.1.2 The validity of the Miyake et al. (2000) model
The Miyake et al. (2000) model adopted had a number of practical benefits, including an associated applied research base and tasks available that purport to capture the three core component skills. However, critical comment needed to be engaged with.

Miyake and colleagues (2000) had made an assumption regarding underlying causal latent variables and specifically the core components of EF. Critical researchers had questioned the direction of causality (Willoughby et al., 2014), but in fact found that Miyake et al.’s work (2000) bore their initial statistical scrutiny. However, a residual concern remains: if Miyake et al. (2000) had made different initial hypotheses about the nature of EF, they may have chosen their task sets differently and arrived at an alternative model. This researcher accommodated this issue largely through precedence: prominent researchers’ acceptance and use of the three core components (e.g. Best et al., 2009; Diamond, 2013).

4.2.1.3 Comparing Miyake et al.’s (2000) model with others
Davidson et al.’s (2006) research appeared to suggest some kind of limited EF capacity within which the component skills were jostling for attention and processing capacity and this started to give a steer for how to reconcile the Miyake et al. (2000) model with other descriptions of cognitive control. The deliberation was captured to an extent in the first expert group, see below, as at this point this researcher had not reached a conclusion. Section 2.4.2.1 represents a later synthesis. Detailed consideration was important because of the impact on theoretical mechanisms for intervention.

4.2.1.4 The nature of Shift
Gaining an in-depth understanding of the nature of Shift was also work in progress at the time of the first expert group. (Section 2.4.2.3 represents a later synthesis.) This researcher was attempting to outline what variations in task would make the Shift requirement more challenging and so suggest intervention mechanisms at task level. These would need to mesh with the underlying theoretical model.
4.2.2 The first expert group interview

Information sent before the first group reflects the researcher’s unfinished state of thinking at this point, see Appendix 4.1. The interview schedule is in Appendix 3.3. After the group, a thematic map and commentary were sent to the experts for feedback. They were accepted without amendment and since the experts were also familiar with Thematic Analysis, additional inter-rater reliability checks were not used\(^1\).

The final thematic map can be found in Figure 4.1 below. It reflects this researcher’s preoccupations at the time and how these were developed within the group. For example the refinement of metacognitive strategy was discussed as a main mechanism of Shift development. This indicates how the conversation went beyond typical interview responses to a schedule. More detail is given under thematic headings.

---

Figure 4.1: Final thematic map for first expert group

---

\(^1\) They had not been planned for this reason.
EF as a limited pool of attentional resource

EF as attentional resource of finite capacity was recognised by the experts as a model legitimised by literature, “some models of working memory just say that it is … a pool of attentional resource that gets diverted to different functions”. In turn this allowed discussion of the logical consequences for a Shift intervention, “You've got this matrix here, if you add up Switch, Working Memory load and Inhibition this gives a sense of the total attentional load”. Increasing the Inhibition and Working Memory requirements could make the Shift aspect more difficult by both reducing available dedicated capacity but also by increasing the load overall. A heavy load for all three EF components could turn an intervention into “a more general training programme for attentional capacity full-stop” that increases ability “to juggle and manage them all”. Task difficulty would then be defined both in terms of Shift difficulty and overall capacity requirement. Mechanisms of benefit could involve “not just improving Shift but improving a bit of Working Memory and improving a bit of Inhibition as well”. It would be necessary to decide whether to keep the intervention “as a Shift intervention, in which case the only thing … to manipulate the difficulty of would be the Shift element” or “maintain the focus on Switch and include Working Memory loads and Inhibition loads to make the activities more challenging and therefore engaging for those more able students”.

If EF were being seen as a finite resource, then it would be important to recognise that working at full capacity can only be sustained for short periods, “if you hit that breaking point where you're demanding too much from their attentional resources to be sustained then they will just switch off or they'll pace themselves throughout, they won't actually stretch it, they'll just be taking their slow walk”. Intervention Structure

Leading immediately on, the consensus was that short bursts of intense activity would be most effective in keeping with the idea of distributed practice: “it’s definitely backed up by research that you need high-impact, short-burst intensive training to improve underlying cognition”. Paired working was one way this could be accommodated.
EF Development

Also leading on from the structure of EF, was the modified conceptualisation of EF development, “a development of increased capacity to juggle and manage them all” i.e. the three component skills. It was felt to be important to consider likely adolescent skill levels "maybe we do need to have a level of 'let's make sure everybody's up to speed on Shift', but beyond that … should be working on a slightly wider composite task."

Framework

Overall the framework was described as “broken down so nicely in the various different areas” and there was brief discussion about the dimensions. For example about Shift, “it's about the predictability of Shift as much as anything, that makes that harder or easier", “double switch to make it harder .. a switch task and interleaved with that .. a change in response task .. Or possibly combining two forms of Stroop, you know something like a word Stroop with an animal Stroop.”

The framework seemed to provide a way to look at EF tasks in terms of several skills, not just the one they are purported to embody. For example, “Stroop itself (an Inhibition task) you can turn into a Switch task by basically chopping the big sheets up into little cards and shuffling them”.

Other task skill requirements captured by the framework were mentioned briefly, “You have to know colour don’t you, and be able to name and label colours?” and this was linked to a short discussion about how the pilot work had been useful in identifying tasks that would be unlikely to work in practical terms, “which ones are likely to work in a whole class rather than in a small group …. too fiddly and lots of pieces.”

Metacognition and feedback

Metacognition was arguably implicitly recognised as residing in EF alongside the three basic core components. As a link between EF components and EF as a limited attentional resource, it was suggested as a mechanism of improved core skill coordination, “this training has to bring in the meta-cognitive side to be useful,” this through intense short periods of engagement with tricky tasks giving feedback to allow some accuracy. “In terms of a Switch task, you do need to know if you’re
getting it right or wrong … if they get it all wrong and just give you the colour the whole time, they actually haven’t done any Shifting at all”.

Learning Hierarchy

The relevance of the Learning Hierarchy per se was debated, “I think it is just a fundamental difference between learning of knowledge and skills and improving … underlying cognitive abilities.” The role of feedback was agreed as an area of difference: for cognitive skills it draws attention to error and therefore promotes a change in metacognitive strategy, whilst for knowledge acquisition it is a direct reflection of skill acquired.

To conclude in terms of process, the first expert group served to progress and clarify this researcher’s thinking. Thereafter, it was the above analysis of discussion that sufficiently satisfied the interview questions to allow theoretical development to move on.

4.2.3 Later theoretical exploration before the second expert group

After the first expert group, this researcher had the confidence to create an initial new EF model, see Figure 4.2 below, based on Baddeley (2012). Conceptualising EF in this way then had consequences for Shift intervention, as explored in the first expert group:

a) Shift skills themselves could be stretched and developed, but also
b) EF as a whole could be challenged by loading requirements for all three components.

These two aspects would never be separable since EF was now being seen as a finite attentional resource. These theoretical mechanisms in turn seemed to have consequences for the initial Shift task matrix: a rearrangement so that it indicated task difficulty in a systematic way. This process was assisted by the creation of descriptions of typical task Inhibition, Working Memory and Shift skill requirements in separate dimensions, with simplifying discrete difficulty levels, see Table A4.2 in Appendix 4.2. The levels were this author’s synthesis of the research describing Shift task detail (Section 2.4.2.3).
Figure 4.2: A model of EF intended to show its limited capacity

This allowed the second matrix to indicate a task’s approximate EF component skill requirement levels though its relative position, see Figure 4.3. The intervention focus, Shift, was used for the top-level structure. Within each level of Shift difficulty is a 3 x 3 grid showing how Working Memory and Inhibition requirements can co-vary. Tasks from the first matrix could then be inserted into the second, and additional tasks could be identified and/or developed to fill the gaps, to ensure an intervention for a broad range of adolescents. It would need to stretch existing Shift skills and develop the ability to juggle skill requirement.
**Figure 4.3: Matrix of EF variation**

<table>
<thead>
<tr>
<th>Shift 1: switch/shift between trial blocks – not really a Shift task, as laid out in basic paradigm</th>
<th>Shift 2: regular switch/shift within trial blocks</th>
<th>Shift 3: irregular switch/shift within trial blocks</th>
<th>Shift 4: irregular switch/shift within trial blocks and irregular switch between different switch tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inhibition</strong></td>
<td>1: Each stimulus provokes only one S-R pair. Levels 2 and 3 provoke at least 2.</td>
<td>2: no prepotent or well-rehearsed responses involved</td>
<td>I2: The most pure Shift tasks – do first to develop Shift skill. Switch is randomly but clearly cued.</td>
</tr>
<tr>
<td>I2: no prepotent or well-rehearsed responses involved</td>
<td>I2: Inhibition provokes at least 2.</td>
<td>I1: as I2 (left), but with prepotent responses involved.</td>
<td>I1: as I2 (left), but with prepotent responses involved.</td>
</tr>
<tr>
<td>I3: a proportion of the responses involved are prepotent or well-rehearsed</td>
<td>I3: as I2 (left), but with prepotent responses involved.</td>
<td>I3b: Item cards – switch is randomly less clearly cued.</td>
<td>I3: as I2 (left), but with prepotent responses involved.</td>
</tr>
<tr>
<td><strong>WM1</strong>: high meaning cues provided and single task</td>
<td>Task is: Shift 1 WM1 I1</td>
<td>Task is: Shift 1 WM1 I2</td>
<td>1d: The most pure Shift tasks – do first to develop Shift skill. Mixes of 1c.</td>
</tr>
<tr>
<td>Task is: Shift 1 WM1 I2</td>
<td>Task is: Practice tasks</td>
<td>2b: Cards - alternating switch must be remembered.</td>
<td>5b: as I2 (left), but with prepotent responses involved.</td>
</tr>
<tr>
<td>Task is: Shift 1 WM1 I3</td>
<td>Task is: Practice tasks – no shift but with higher Inhibition.</td>
<td>3a: as 2b (left) but with prepotent responses involved.</td>
<td>5b: mixes of 3b (left).</td>
</tr>
<tr>
<td>2a: Practice tasks</td>
<td>Task is: Shift 2 WM1 I1</td>
<td>3b: Item cards – switch is randomly less clearly cued.</td>
<td>6a: as either 5b with irregular cued NOGO.</td>
</tr>
<tr>
<td>Task is: Shift 2 WM1 I2</td>
<td>1b: The most pure Shift tasks – do first to develop Shift skill. Switch is cued every 1/2/3/4 items.</td>
<td>4b: as 3b left but with irregular cued NOGO OR 3b (above) with irregular cued NOGO.</td>
<td>6a: 6 abstract shapes mixed with other non-prepotent task.</td>
</tr>
<tr>
<td>Task is: Shift 2 WM1 I3</td>
<td>Task is: Shift 2 WM1 I2</td>
<td>4b: as 3b left but with irregular cued NOGO OR 3b (above) with irregular cued NOGO.</td>
<td>7: As 6a (above) with NOGO condition to be remembered or as 6a (left) with irregular cued NOGO.</td>
</tr>
<tr>
<td>Task is: Shift 2 WM1 I3</td>
<td>Task is: Shift 2 WM1 I2</td>
<td>4b: 6 abstract shapes OR composite of 1c/3b above.</td>
<td>6a: 6 abstract shapes mixed with other non-prepotent task.</td>
</tr>
<tr>
<td>Task is: Shift 2 WM1 I3</td>
<td>Task is: Shift 2 WM1 I2</td>
<td>4b: 6 abstract shapes OR composite of 1c/3b above.</td>
<td>7: As 6a (above) with NOGO condition to be remembered or as 6a (left) with irregular cued NOGO.</td>
</tr>
</tbody>
</table>

**Key:**
- WM is Working Memory and I is Inhibition.
- Grey shading indicates tasks that are theoretically impossible.
- ‘6 abstract shapes’ is a task loading heavily onto WM.

For clarity specific tasks are not included. Instead the boxes within Shift level 1 have skill combinations indicated. It is largely assumed that these can be extrapolated for the other Shift levels.

Intended task order would be: 1a, 1b, 1c, 1d, 2a, 2b, 3a, 3b, 4a, 4b, 5a, 5b, 6a, 6b, 7.
Within the matrix, tasks at the top left are easiest as they have lower loadings on all three component skills and tasks at the bottom right should be the hardest, with higher loadings on all three component skills. As such, the hardest tasks would need to be created as none equivalent had been located in the literature.

With this structure, the matrix also provided suggestions for task presentation order, the aim being to develop Shift skills first and then challenge EF as a whole, see Figure 4.3.

4.2.4 The second expert group interview

Materials sent before the second expert group consisted of the initial new model of EF see Figure 4.2 above, the matrix shown in Figure 4.3 below, a further matrix of similar format containing suggestions for specific tasks at the various difficulty levels\(^2\) see Appendix 4.2 and examples of particular tasks, see Appendix 4.2. The questions to be asked of the experts can be found in Appendix 3.3. The role of this second group was anticipated to be more about verification and less about guidance.

Figure 4.4: Final thematic map for second expert group

\(^2\) These were primarily from earlier work (Darby, 2013b) or Davidson et al. (2006).
As for the first group, a thematic map and commentary were sent to the experts for feedback and they were accepted without amendment. Again, additional inter-rater reliability checks were omitted. The final thematic map, Figure 4.4 above, reflects a need for feedback regarding the new matrix and associated tasks. It also reflects additional conversation around the uncertainties inherent in research of this kind. The themes are discussed in some detail below.

**Task matrix: structure and coverage**

The task matrix was seen to incorporate key task dimensions, the main focus Shift, but also Inhibition and Working Memory. Further, that the structure made clear the approximate level of difficulty, “would I be right in thinking roughly, that they would be easy .. those 2 to 4 mostly would be medium .. that's the hard stuff, the bottom right-hand corner?”, “so you could draw diagonal lines down of load?”

In turn this was seen to allow systematic and useful variation in task difficulty that should provoke crucial metacognitive activity, “by having it in this matrix, .. having that stepped approach, is working the overall capacity, … it's really working on the meta-cognitive aspect of it because kids are, will be very aware of the difference .. how they're finding these individual tasks a little bit easier because of lessening load based on working memory and things like that.”

Tasks theoretically loading lightly on all three dimensions were seen as suitable introductory activities, “using sort of like the beginning bit of the matrix as a chance to get familiar with the different tasks that will be involved.” By contrast the tasks loading heavily on all three dimensions might be difficult for anyone to perform well on, but they were important for providing challenge, “could have some very clever Year 8s” and “if they engage with the task, and understand the task, and they make some mistakes, never mind they’ve nevertheless stretched themselves.”

**Overarching characteristics**

Experts also drew attention to characteristics that needed to be considered across the matrix. All materials would need to be properly usable. Firstly, the tasks would need to be experienced as intended. Where cards are involved this would require them to be correctly oriented and in some instances for the stimuli to be seen relative to a mid-point. Solutions were discussed, “cutter .. you cut the corner out so that .. it means that automatically they are the right way round” and
“it will be important that they are a sufficient size and are centrally centred so that the picture is on the left or right of the mid-line of that person.”

Secondly, sensory processing requirements needed to be low, “requirement for visual discrimination and all that kind of thing, should all be at a low level regardless.”

Finally, it would be important for motivation to be sustained in the face of necessary increasing difficulty “as they’re the most difficult they can also run the danger of affecting motivation the most.” Self-management and revisiting easier task levels were felt to be appropriate strategies for managing current task difficulty, “we’d ask them to move on when they’re not making mistakes and they feel like they’re answering fairly quickly” and “bounce back to a more basic task from time to time.”

**Repeating content**

Experts felt that having a limited number of tasks in the intervention could bring benefits, including enhanced noticing. Processing the same contents in slightly different ways might enhance metacognition, “the same materials .. but what they have to do with them will make them feel different.” Explicit discussion was suggested as an option, “you could hold some discussions with the kids on talking about why the tasks are different, or you could just leave them to it and see whether it naturally induces meta-cognitive awareness.”

It would also give a steer on which tasks to use or develop, according to their potential for variation. A specific example (6 abstract shapes) was discussed that focusses on Working Memory but that could be adapted to increase Inhibition load, “these 3 shapes would be sorted to the left and these 3 to the right and you would have to remember that. Now the logic would be that if you then made cards with the shape printed on one side or the other, say if it was left, you would tend to want to sort that to the left but actually if it’s to go in the right-hand pile, you’ve got your Simon effect or prepotent response kicking in there.” Although there was a theoretical rationale for such task modifications, experts felt it could be beneficial to try out new variations before putting them into the intervention, “You can just take it along and get some kids play with it, do it in a really pragmatic manner and don't interview the kids don’t do anything else like that. Just write it up saying “did a play test observation to see how they used them, and they worked fine or I made
these amendments based on that.” Existing tasks that couldn’t be used in the main intervention could be used as group warm-ups, "group 'knock and tap' as a warm-up .. gets everyone kind of in the zone .. especially in the first week”.

Also having fewer but repeated tasks seemed a good fit to context. With just 15 to 20 minutes per session, easy self-management would be important, “the fewer tasks you have, the easier it is to implement within the school”, “it might be Monday as Stroop day, early weeks of Stroop day would be possibly on these sheets or, and then you might go through the card phase with the cues.”

The research and development process

Within this second main theme were others: developing a suitable underpinning theoretical model, developing an intervention that might not work in the classroom and more generally feeling responsible for something that has yet to fully crystallise.

Underlying model

Residual doubts about the suggested EF model were discussed and resolved, “within the Central Executive, say if you have the information coming through either in a verbal or a visual form from the phonological loop or from the visuo-spatial sketchpad, as that gets into Central Executive, that will spark information to come from the episodic buffer” and “whether the sensory input accesses the schema first or the Central Executive first, the onus is on building the Central Executive.” Resolution at this stage was thought to be positive, “It's important to clarify, especially for thesis, 'cos when you write it up that can be a key thing that might pop up in a viva, so having been through this process, you are in a really strong position.”

New intervention materials

This subtheme reflects the realisation during the second expert group that for the matrix to be fully populated with a limited number of base tasks, as suggested by the group, there was potential for task variants to be included in the intervention without piloting, “I know theoretically it does induce this Simon effect and Inhibition and all that but a part of me can't quite believe that just having it printed on that side is going to make you more likely to sort it to that side”.

112
Research uncertainty

This sub-theme reflects a general sense of disquiet at what had been promised in the research, “this all feels a bit scary, I'm not sure what I'm doing here!” The group provided reassurance, “trust in yourself because you're the expert when it comes to that, you're the expert of the matrix, it's your matrix” and “there's always going to be a phase in development when you're doing research where you're not sure how it's going or where it's going to.” The experts also provided advice about interpretation of the initially proposed outcome measure “it hasn't been standardised or validated across other tests .. it's an indication sure but it's very difficult to kind of make a firm conclusion.”

4.3 The development of an intervention prototype

Overall, the second expert group was able to provide the verification needed to then translate the theoretical work into a prototype first version to present to the stakeholder group. The middle section of Figure 3.1 is pertinent here.

4.3.1 Practical development of first version prototype

After the second expert group, this researcher felt more confident in proposing mechanisms of benefit. Firstly, training on Shift tasks could develop Shift skill per se and have near effect benefit on all EF components, through practice at juggling a limited resource. Secondly, tasks that step up in difficulty, especially where they use the same content, could provoke query and reflection and hence develop metacognitive strategy.

In addition this researcher was also equipped with a rationale for selecting a limited number of tasks for final modification: i) tasks that could appear at several difficulty levels and such that sufficient difficulty could be ensured even for Year 8s with excellent EF and (ii) where possible, tasks that had been trialled previously.

The next task then was to consider all the practical issues previously identified and respond to them with an intervention design useable in the particular context: 15 to 20 minute slots in Year 8 morning form-time. The issues and responses (latter shown in colour) are summarised in Figure 4.5 below. The contributing sources were several literature areas (EF (EF), flow (F), implementation (I), social mediation and cooperation (SM) and comic strip conversations (C)), this researcher’s previous work (D) and the two expert groups (EG1, EG2). In Figure 4.5, these abbreviations indicate the relevant source.
4.3.2 The stakeholder group

The stakeholders requested to not be sent any information before the focus group, but instead to try the intervention just before and during discussion. The materials taken consisted of a version of the task matrix, a list of core tasks that could appear at more than one difficulty level, a booklet for students intended to allow self-management in pairs and some examples of the tasks, see Appendix 4.3. The focus group prompts can be found in Appendix 3.3.

Having stakeholders assembled was also an opportunity to also gather essential information. They reported that no one in the form had sensory processing or motor coordination difficulties and that school would provide timers.

Before any data analysis took place, this researcher took the transcript into school to allow member checking, by each participating stakeholder in turn. Several days later and before any changes were made to the first version prototype, an intermediate thematic map, see Appendix 4.5, and theme descriptions were discussed with members of the stakeholder group. Just prior to this, another researcher (a doctor in education familiar with qualitative methods and research ethics) analysed the suggested codes, themes and subthemes. She broadly agreed with them and differences were reconciled by including some quotes in more than one theme, to allow inter-rater consistency.
Figure 4.5: Practical suggestions for the prototype intervention

**Design of prototype intervention, including training**

- **Have tasks that combine skills** for greater generalisability (EF).
  - This is inherent in the model of EF adopted. Also EF tasks have to involve non-executive skills, such as naming.

- **The outcome measure** must challenge (EF) and be robust (EG2).
  - Research modification applied for to allow standardised measure.
  - Match to organisation values (I).
  - School value of innovation met by any research activity.
  - Additional skills such as naming need practice (LH).
  - Tasks low on all 3 EF skills will serve as content/additional skill introductory activities.

- **Tasks to contain novelty**, but to be repeated at more than 1 level of difficulty (D, EG2).
  - Tasks to be modified to fit more than one difficulty level, using tasks previously piloted where possible. Task content should be novel.

- **Design in feedback** to ensure some task accuracy (D, LH) and reinforcement (F), to promote student’s reflection on strategy (D, SM) and to give the facilitator indications of level and progress (SM).
  - Learners could chart their own progress (LH).
  - Students to work in pairs (or threes) helping to record each other’s performance in terms of speed and accuracy, giving each other feedback and engaging in creative/reflective conversations.

- **Shared decision making** (I).
  - Form tutor and intervention facilitator are in the stakeholder group shaping design.

- **Opportunities for repeated, short-burst skill practice** with different tasks (D, LH) and in sufficient dosage (EF, I).
  - Pair members to alternate between practising and observing, on tasks that take typically about a minute.

- **Contact, technical assistance and training** to be available throughout (I), so facilitator feels able to deliver the intervention as expected (D, I).
  - Intervention handed over once facilitator is happy to manage it and feels sufficiently trained. Email and telephone contact always available. Weekly observations to be opportunities to sort technical issues and further training needs.

- **Students to work from current skill level** so that they are engaging with demanding tasks (EF, F, LH), that are not too difficult and that are interleaved with easier tasks (D, F, EG2).
  - Students are encouraged to fast-forward to tasks they find challenging. They revisit a ‘test’ page that is a relatively straightforward Shift task.

- **Opportunities for modelling (LH), vicarious learning (SM) and reciprocal teaching (SM).**
  - All provided for within paired working.

- **Built-in flexibility to allow adaptation to local context** but with core principles maintained (I):
  - at organisational level so that can be fitted into the school day without impinging on high risk lessons/year groups (D, EF)
  - at class/session level.

  - Short self-managed tasks that fit into 15 minute form-time sessions. More or less can be used depending on degree of interference from other class business that day.

  - Match to organisation values (I).
  - School value of innovation met by any research activity.

  - Additional skills such as naming need practice (LH).
  - Tasks low on all 3 EF skills will serve as content/additional skill introductory activities.

  - Students to work from current skill level so that they are engaging with demanding tasks (EF, F, LH), that are not too difficult and that are interleaved with easier tasks (D, F, EG2).
  - Students are encouraged to fast-forward to tasks they find challenging. They revisit a ‘test’ page that is a relatively straightforward Shift task.
Figure 4.6 shows the final thematic map. The first theme to emerge had been the need for school staff to get a feel for the intervention and what it would look like in the classroom. The needs of the different participants were considered: the students, the facilitators and the school as an organisation. An overarching theme arising repeatedly was that students must be able to navigate through the intervention in an orderly fashion. The themes are elaborated below.

**Getting a feel**

In wanting to know how the intervention would play out in the classroom, the stakeholders explored their understanding of the student role, the facilitating role and what materials would be needed.

Regarding the roles, stakeholders were keen to summarise their perceptions and to get feedback. This included the way students would interact with individual tasks according to rules, “*So the ‘S’ is for shape*, “*record the mistakes on like a tally or something?*” and how they would self-manage their way through the intervention, probably working in pairs, “*different sorts of tasks, that they are going to work through*, “*they need to get stuck then get unstuck don’t they?*” and “*they’ll say "Sir I don’t get this" but they’re not allowed to do that are they if they are self-managing it all*”. This particular comment allowed brief feedback to the effect that the intended self-management did not preclude facilitator support.

**Figure 4.6: The final thematic map for the stakeholder group**
Discussion about the facilitator role mainly concerned the preparation and training needed, “In the initial phase .. are you coming in to explain to the students or is xx or yy going to be the person who stands there and explains what the process is?” and “definitely need to know all these tasks and how they work so, because you know that as soon as the kids start initially they're just going to go “whoah”.”

It was also important to get a sense of what the final intervention prototype materials would be like, and to clear up an ambiguity about the responsibility for creating them. “how many sets would we need for the whole class?”, “are we going to have them in different boxes for different levels?” and “Will you be producing those?”

As a way of fully grasping these aspects, a classroom trial was suggested, “I need have a go at it, that's what I need to do .. get a sample few kids, to just say “Right, this is an activity we want you to try, there's the booklet, there's the boxes, you go and”. And see if they can do that. I'd like to see that happen before I go in and start the work really.”

**Orderly intervention navigation**

This was an overarching theme with a number of facets. Linking with the previous theme, there was a sense that students’ ability to navigate in an orderly fashion needed to be seen to be believed. The possibility of disorderly student engagement caused the stakeholders anxiety, both in terms of losing authority within the classroom and having students leave form-time late. It also linked to students’ needs, with stakeholders suggesting they would give up if the materials were not easy to access. This theme also contained suggestions for how the first version prototype could be usefully developed/changed.

The process within each intervention session needed to be sleek, “I like the idea of the booklet because it's just all there” and “they're coming in and they're picking up a booklet, a stopwatch and something out of a box”, but changes to the materials would be needed. Firstly a reduction in booklet information, “I'd highlight what they actually need there .. I could skip the rest of the information”, “I think you have made quite a simple concept difficult here. .. they don’t know what stroop means to start with so – it's just far too much information”. Secondly each task should have dedicated and well labelled materials to support it, “just go to the box with Task A written on it” and “graphics on the front of the box.. pictures rather than words.”
The task rule could be located on the box lid and/or with each set of materials. “Couldn't that rule be on the box with the cards in it?” or “stick a label on the outside (of the packet) .. so then they can take it away with them.” Thirdly the materials needed to be easier to put away again, “How difficult would it be to put something on the back to say where they came from?”

Students’ needs

This sub-theme again included reducing student information as well as some allusion to task and material acceptability and to ownership.

In terms of intervention structure, there was some debate as to whether a single guiding student booklet was preferable or a series of smaller ones. “I like the idea of the booklet 'cos then they've got the ownership” versus “make the booklet smaller but more of them, so they're progressing through booklets as well and think "Oh I'm on booklet 3 or.”

Whichever was finally chosen, stakeholders felt that the pages needed to be de-cluttered and easy to read, “reduce the number of tasks on a page”. They conveyed a perception that if the materials weren't immediately intuitive, the students would not engage, “they're just going to go "whoah" if it's not immediately apparent and clear and simple.”

The stakeholders seemed to think the tasks themselves would be acceptable. They would bring some novelty and these students are used to doing as they are told, “they'll think "Ooh" “ and “They'll just accept it won't they, if we just tell them we're doing it, they'll just say "Yeah, we're doing it".

There was some specific discussion about card usability: laminated card durability versus the preferable feel of uncovered card, “I like the feel of card but are they durable enough? It depends how many times they do it … the laminate doesn't feel that nice does it, I agree but it might just last?” and also whether tasks should be presented portrait or landscape, “Oh no, they're all weird .. See I'm tending to turn these that way round .. they go better in my hand .. So maybe the kids will do that, as a deck of cards.”

Facilitator needs

Facilitators all expressed the need to preserve classroom order, but differed in their need to maintain students’ perceptions of their skills.
Thinking about potential classroom chaos, there was a hint that self-management would have to be compromised if this were necessary to keep order, “I don't know how you're going to keep this organised, I'm terrified”, “if I dish all that out to the kids, .. I could just see everything getting lost and I think it would just turn into chaos, full of cards all over the floor,” but “if we did so many tasks per day and just gave them the cards for those 3 tasks would that make life easier? .. We wouldn't need them all out then.”

One stakeholder who would be in the classroom seemed threatened by the tasks, “I had a look at it before, that one, and I'm thinking "Jesus!", yeah .. I don't want to know what I am. I'll be honest!” whilst another laughed saying, “So we'll be really rubbish at it!”

School needs

The voiced needs of the school as a whole were to make sure that materials conformed with its Dyslexia Friendly status, “for school rules, we'll have to have it on cream paper” and to ensure that students were on time to their first lesson with form administration complete, “with the timeframe we've got in the morning .. it's you know, can we get through this in 15 minutes .. I wouldn't say that was a quality 15 minutes either.”

4.3.3 Creating a package for classroom evaluation

A prototype intervention was now put together for classroom evaluation. Tasks were created for all the matrix cells from versions and mixtures of the ten base tasks harvested from the literature and presented to the stakeholder group. A number of changes were made in response to stakeholders’ suggestions.

i) A one-to-one correspondence was created between each task in the student booklet and the materials to accompany it. For example, for the A task, the booklet now said, “You need: A cards and”. All cards would be in boxes and all sheets in folders. A cards would be in Box A.

ii) All cards were now labelled on the back, for example A, to help with tidying away. Cards were kept in packs by rubber bands, as these were faster and easier to use than packets and easy/cheap to replace.

iii) All materials were laminated for durability.
iv) Whole intervention booklets were retained to promote ownership, but task rules were removed to de-clutter appearance. For tasks on sheets, the rule was presented across the bottom of the sheet. For card-based tasks the rule appeared on an additional card, without a corner notch removed so that it could be easily located within the pack. Feedback tables (errors and time taken) were provided for all tasks to give uniformity of process throughout.

Samples of the materials can be found in Appendix 4.7. The complete package can be found on the accompanying CD.

Once these changes had been made for the first six tasks of the intervention, the researcher took the prototype into school so that participating staff could satisfy themselves regarding changes made. The teaching assistant took the materials into a lesson she normally supported and asked for volunteers to try them out. Eight Year 7 students each took a booklet and attempted to navigate their way through in pairs for about 20 minutes. The researcher used the opportunity to give some training by modelling interactions with students that might support useful discussion within the pairs. The teaching assistant was pleased at how the students managed and with their enthusiasm. She was now keen to start the intervention with the Year 8 form group and wanted no further training herself.

The complete prototype was put together for the intended start date after the February half term holiday. A page of additional notes was created for facilitators, see Appendix 4.7, in recognition of the fact that all stakeholders had been preoccupied with getting a feel for the practical issues rather than understanding the skills the intervention was trying to develop. It was hoped that the notes would be increasingly referred to during the intervention, once the facilitators were reassured that the sessions were running with some stability and orderliness. They included prompts to ensure students were working on appropriate tasks and engaging in some metacognitive discussion.

The package delivered to school for the evaluation comprised:
- 25 booklets (1 per student plus spares)
- 2 administrator booklets, the same as the students’, but with the additional guiding notes mentioned above
- tasks presented on sheets collated into marked folders and
- tasks presented as card bundles stored in eight marked plastic boxes (roughly 1
litre capacity). Earlier tasks each had their own box, whilst later ones were stored two or three to a box, to balance ease of location of task with storage of the package as a whole.

A hypothetical example of an intervention session using these materials is given in Appendix 4.8.

4.4 The implementation evaluation

This results section covers the implementation i.e. whether or not the intervention ran with some smoothness and whether or not it produced any measurable or perceived benefit. The middle and final sections of Figure 3.1 are pertinent here.

4.4.1 Quantitative data analysis

The standardised data were analysed firstly to see whether or not there were positive results to report. They were then analysed to see if there were changes in the way the participants were performing, specifically those showing least and most improvement. Lastly the data were used to annotate a diagram of the classroom to see if any tentative patterns emerged. This last step required some integration of quantitative data with qualitative diary data.

Appendix 4.10 lists the following NEPSY-II Inhibition subtest data scores for each participant: raw scores, standardised scores and corrected retest standardised scores. The pre-test standardised scores are also shown graphically. Unless explicitly stated otherwise, the quantitative results reported below draw on the standardised NEPSY-II data, including more specifically the retest data that was corrected using the techniques outlined within the methodology chapter.

For Naming, the resulting mean combined scaled scores before and after the intervention were 5.3 and 7.2 respectively, for Inhibition they were 7.1 and 8.0 respectively and for Switch they were 6.5 and 7.8 respectively. Score means are given corrected to 1 decimal place. These changes are shown graphically in Figure 4.7.

3 For comparison, Figure 4.7 also shows the uncorrected retest score means. For Naming, Inhibition and Shift these were respectively 9.0, 10.4 and 10.2 and these values can be verified from individual retest combined scaled scores given in Table A4.7.
The data distributions (see Appendix 4.10) together with the sample size of 22 precluded the use of parametric statistical analysis. Instead, the Wilcoxon matched pairs test was applied, see Figure A4.14 in Appendix 4.10. For Naming, $T=19.5$, $n=17$ (5 score pairs equal); this is significant at the 99.5% level, for a one-tailed test. For Inhibition, $T=50.5$, $n=17$ (5 score pairs equal); this is not significant for a one-tailed test. For Switch, $T=39$, $n=20$ (2 score pairs equal); this is significant at the 97.5% level, for a one-tailed test. The associated effect sizes are as follows: for Naming, Cohen's $d=0.90$ and the standardised response mean = 0.71, whilst for Switch, Cohen’s $d=0.48$ and the standardised response mean = 0.60. These could be considered large and medium sized effects respectively.

The effect sizes were calculated as follows and see Appendix 4.10:

Cohen’s $d = \frac{\text{difference in means}}{\text{standard deviation of first data set}}$.

Standardised response mean = \frac{\text{difference in means}}{\text{standard deviation of differences}}.

---

$^4$ Two different calculations prior to the study had suggested minimum sample sizes of 25 and 27 for sensible use of inferential statistics, see Appendix 4.10. However, post hoc power calculations give the power values associated with Naming and Switch combined scaled score changes as 0.93 and 0.84 respectively, values that are at least acceptable.

$^5$ To reiterate, the effect size calculations drew upon the corrected retest data, as did other statistic calculations.
The contrast scores (with retest scores based on the corrected combined scaled scores) were used to identify any relative improvements. For Naming-Inhibition contrast, the mean scaled scores before and after the intervention were both 9. So skills for Naming and Inhibition appeared to be unchanged relative to each other for the group as a whole. For Inhibition-Switch contrast, the mean scaled scores before and after the intervention were 7.5 and 8.4 respectively. This appeared to show that Switch skills on average showed relative improvement compared with Inhibition skills. Score means are given corrected to 1 decimal place. These changes are shown graphically in Figure 4.8⁶.

To see if the changes in Inhibition-Switch contrast scaled scores were significant, the Wilcoxon matched pairs test was again applied. For the Inhibition-Switch contrast scaled scores, T=49, n=18 (5 score pairs equal) and this is non-significant for a two-tailed test. (For 90% significance T must be less than or equal to 47.) The calculations can be found in Appendix 4.10.

So far then, it seems that Switch and Naming performance improved, that the mean change in Inhibition performance was not significant and that the apparent improvement of Switch relative to Inhibition skills was not significant.

---

⁶ For comparison, Figure 4.8 also shows the mean uncorrected retest contrast scaled scores. For Naming-Inhibition and Inhibition-Switch these were respectively 10.9 and 9.9. These values can be verified from Table A4.9.
Mean values mask a mixed picture, as shown in Figure 4.9. So to see whether improved Naming and Switch performance were due to particular changes in skill and strategy, two groups of participants were created that seemed to have demonstrated greater skill change, see Tables 4.2 and 4.3.

The groups were created according to greatest change in corrected scores. However the tables present the uncorrected and raw scores, since it is absolute change that is being explored here.
Figure 4.9: Bar charts showing changes in performance for each participant
In each case the double (time and error components) correction has been applied.

**Changes in combined scaled scores:**

(a) Naming

(b) Inhibition

(c) Switch

**Changes in contrast scaled scores:**

(a) Naming-Inhibition

(b) Inhibition-Switch
Table 4.1: Participants making most apparent progress with Naming skills

<table>
<thead>
<tr>
<th>Participant number (Sex)</th>
<th>Naming combined ss*change (Switch combined ss change)</th>
<th>Before intervention:</th>
<th>After intervention:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Naming time ss (raw score/s)</td>
<td>Naming time ss (raw score/s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Error band7 (no. errors)</td>
<td>Error band (no. errors)</td>
</tr>
<tr>
<td>2 (M)</td>
<td>6 (0)</td>
<td>7 (50) &lt;2 (9)</td>
<td>7 (47) 51-75 (0)</td>
</tr>
<tr>
<td>9 (M)</td>
<td>9 (1)</td>
<td>7 (48) &lt;2 (4)</td>
<td>14 (33) 51-75 (0)</td>
</tr>
<tr>
<td>13 (F)</td>
<td>6 (7)</td>
<td>10 (41) 2-5 (2)</td>
<td>14 (34) 51-75 (0)</td>
</tr>
<tr>
<td>15 (M)</td>
<td>7 (4)</td>
<td>3 (72) 2-5 (2)</td>
<td>7 (50) 51-75 (0)</td>
</tr>
<tr>
<td>22* (M)</td>
<td>6 (9)</td>
<td>8 (45) 2-5 (2)</td>
<td>9 (41) 51-75 (0)</td>
</tr>
<tr>
<td>23 (F)</td>
<td>8 (6)</td>
<td>9 (41) &lt;2 (3)</td>
<td>14 (33) 51-75 (0)</td>
</tr>
</tbody>
</table>

*ss is to mean scaled score

Table 4.2: Participants making most apparent progress with Switch skills

<table>
<thead>
<tr>
<th>Participant number (Sex)</th>
<th>Switch combined ss change (Naming combined ss change)</th>
<th>Before intervention:</th>
<th>After intervention:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Switch time ss (raw score/s)</td>
<td>Switch time ss (raw score/s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Error band (no. errors)</td>
<td>Error band (no. errors)</td>
</tr>
<tr>
<td>1 (M)</td>
<td>7 (2)</td>
<td>11 (83) 11-25 (9)</td>
<td>13 (66) &gt;75 (2)</td>
</tr>
<tr>
<td>5 (F)</td>
<td>8 (1)</td>
<td>11 (91) 11-25 (10)</td>
<td>15 (62) &gt;75 (2)</td>
</tr>
<tr>
<td>6 (M)</td>
<td>4 (1)</td>
<td>3 (136) 2-5 (11)</td>
<td>7 (108) 11-25 (5)</td>
</tr>
<tr>
<td>11 (M)</td>
<td>5 (6)</td>
<td>7 (111) 11-25 (10)</td>
<td>12 (75) 51-75 (3)</td>
</tr>
<tr>
<td>13 (F)</td>
<td>7 (6)</td>
<td>11 (84) 11-25 (8)</td>
<td>14 (65) &gt;75 (2)</td>
</tr>
<tr>
<td>22* (M)</td>
<td>9 (6)</td>
<td>2 (139) &lt;2 (36)</td>
<td>4 (124) &gt;75 (0)</td>
</tr>
</tbody>
</table>

* This participant requested time to recover after the retest – it had been effortful for him.

These tables appear to show that positive change has been contributed to by increases both in speed and accuracy, but with greater contributions from

7 Error bands are by percentile: <2, 2-5, 6-10, 11-25, 26-50, 51-75, >75
improved accuracy. The changes in Switch and in Naming appear unrelated, as indicated by comparing the two score changes. Therefore, improvements in Switch scaled scores are unlikely to be attributable to underlying improved Naming skills.

It seemed worth comparing this with what had happened for those making least progress. Equivalent tables were created, see Tables 4.4 and 4.5 below. From these it would seem that participants making least progress tended to show little change in either speed or accuracy. It also becomes apparent that small changes in performance can create seemingly large changes in score, for example participant 18’s move from band 51-75 to 11-25 was for making a single mistake. Therefore individuals’ performance must be interpreted cautiously.

Table 4.3: Participants making least apparent progress with Naming skills

<table>
<thead>
<tr>
<th>Participant number (Sex)</th>
<th>Naming combined ss change (Switch combined ss change)</th>
<th>Before intervention: Naming time ss (raw score/s) Error band (no. errors)</th>
<th>After intervention: Naming time ss (raw score/s) Error band (no. errors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (M)</td>
<td>2 (7)</td>
<td>7 (48) 51-75 (0)</td>
<td>11 (39) 51-75 (0)</td>
</tr>
<tr>
<td>5 (F)</td>
<td>1 (8)</td>
<td>16 (32) 2-5 (2)</td>
<td>16 (30) 11-25 (1)</td>
</tr>
<tr>
<td>6 (M)</td>
<td>1 (4)</td>
<td>6 (55) 2-5 (2)</td>
<td>8 (45) 2-5 (2)</td>
</tr>
<tr>
<td>7 (F)</td>
<td>1 (4)</td>
<td>11 (39) 11-25 (1)</td>
<td>15 (32) 11-25 (1)</td>
</tr>
<tr>
<td>17 (M)</td>
<td>2 (3)</td>
<td>9 (&lt;2) 2-5 (5)</td>
<td>10 (40) 2-5 (2)</td>
</tr>
<tr>
<td>18 (F)</td>
<td>-2 (5)</td>
<td>9 (42) 51-75 (0)</td>
<td>12 (36) 11-25 (1)</td>
</tr>
<tr>
<td>19 (M)</td>
<td>2 (3)</td>
<td>2 (74) 11-25 (1)</td>
<td>6 (53) 11-25 (1)</td>
</tr>
<tr>
<td>20 (M)</td>
<td>-1 (3)</td>
<td>10 (42) 2-5 (2)</td>
<td>8 (43) 2-5 (1)</td>
</tr>
</tbody>
</table>
### Table 4.4: Participants making least apparent progress with Switch skills

<table>
<thead>
<tr>
<th>Participant number (Sex)</th>
<th>Switch combined ss change (Naming combined ss change)</th>
<th>Before intervention:</th>
<th>After intervention:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Switch time ss (raw score/s)</td>
<td>Error band (no. errors)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 (106) 11-25 (8)</td>
<td>6 (114) 11-25 (9)</td>
</tr>
<tr>
<td>2 (M)</td>
<td>0 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (M)</td>
<td>1 (4)</td>
<td>11 (80) 26-50 (5)</td>
<td>14 (64) 26-50 (5)</td>
</tr>
<tr>
<td>8 (F)</td>
<td>2 (5)</td>
<td>11 (83) 26-50 (6)</td>
<td>12 (79) 51-75 (2)</td>
</tr>
<tr>
<td>9 (F)</td>
<td>1 (9)</td>
<td>10 (89) 26-50 (5)</td>
<td>14 (62) 26-50 (5)</td>
</tr>
<tr>
<td>12 (F)</td>
<td>1 (2)</td>
<td>12 (69) 11-25 (6)</td>
<td>14 (64) 11-25 (6)</td>
</tr>
<tr>
<td>14 (M)</td>
<td>1 (3)</td>
<td>10 (84) 11-25 (7)</td>
<td>13 (65) 11-25 (6)</td>
</tr>
<tr>
<td>21 (F)</td>
<td>-1 (5)</td>
<td>11 (91) 11-25 (9)</td>
<td>10 (90) 11-25 (6)</td>
</tr>
</tbody>
</table>

Nevertheless, since reducing errors seemed to be important to making progress, Total Error information is presented for the group as a whole. The mean Total Error scaled scores before and after the intervention were 5.6 and 8.7 respectively. Score means are given corrected to 1 decimal place. These changes are shown graphically in Figures 4.10 and 4.11.

---

8 Again to reiterate, these results draw upon the corrected retest data.

9 For comparison, Figure 4.10 also shows the mean uncorrected retest Total Error scaled score: 10.1. This value can be verified from Table A4.7.
The graph above indicates that the majority of students improved their error levels. To see if the changes overall were significant, the Wilcoxon matched pairs test was again applied. For Total Error scaled scores, $T=27$, $n=22$ (all score pairs different); this is significant at the 99.5% level, for a one-tailed test. The associated effect size is Cohen’s $d=1.14$, or standardised response mean $= 0.86$. 
and so could be considered a large effect. The calculations can be found in Appendix 4.10.

Then, to explore whether students with least initial skill had benefitted the most, two groups were created based on initial Shift combined scaled scores: those with scores in the average range and those with scores below average. There were 11 in each. The corrected mean change for the low group was 1.7, or 1.2 if an outlier was removed (participant 22), see Appendix 4.10 for calculations. For the average group, the mean change was 0.81. This gives some slight indication that those who needed the intervention most also benefitted most.

Lastly a classroom diagram is presented in Figure 4.12. This was created in response to a diary observation and facilitator feedback that the levels and nature of engagement seemed to be in relatively distinct pockets. Black boxes represent the desks. Pink and blue boxes are placed approximately where the students were seated, girls and boys respectively.

\[10\] A post hoc power calculation gave a value of 0.98.
Figure 4.12: Classroom diagram

Key:
First number – participant number. First letter - initial level of standardised Shift scaled score. Second letter - final level. L - ≤ 7, M – 8 to 12, H - ≥ 13, based on NEPSY-II scaled score labels. Text colour indicates score change: red - 0 or negative, orange 1 or 2, green - 3 or higher.

Faces indicate apparent level of engagement overall. 😞 is lower, 😊 is in between and 😎 is higher. Last single letter is the last task attempted from the intervention. If this is green the student had also been interviewed. Quotes are summarised offerings from retesting. Labels with arrows refer to whole table.
Tentatively it would seem that the pocket of non-achievement is on the table where several girls quietly avoided the intervention. The other table of girls self-managed and engaged, whilst the boys were overseen by the facilitator.

4.4.2 Qualitative data analysis
This is given in three sections, two detailing the feedback received through interviews and the other briefly detailing particular information from the researcher’s diary. The interview schedules are in Appendix 3.3.

4.4.2.1 Feedback from the facilitators
After some initial coding, the analyses of the two transcripts were combined. There were a number of common themes emerging and where there was difference of opinion this could be indicated under the relevant theme heading.

For a better understanding of the following analysis, it may be useful to know that the form tutor largely left the running of the intervention to the teaching assistant whilst he carried out form-time business. “I'm a little bit hands off .. it's been fairly straightforward for me .. , I just moan at them and X comes in and does it.” It may also help to review the diagram of the classroom: girls and boys always sat separately.

The final thematic map, see Figure 4.13, was taken with commentary into school for member checking; interviewees did not suggest changes. Inter-rater reliability work was carried out as for the stakeholder group.

Figure 4.13 reflects discussion about the intervention facilitator role and how some aspects of this had varied between the two main perceived groupings in the class: girls and boys. This also links to perceived engagement levels and ability to self-manage. In turn, suggestions for change were generated, these in part in recognition of the fact that socially mediated mechanisms for skill development had been difficult to support. The themes are expanded below under each main theme heading.

Facilitator Role
The teaching assistant conveyed that her role had been less stressful than she had expected, “on the whole it worked really well. I was quite surprised .. I've enjoyed it actually and I just can’t wait to see the results .. it will be really interesting. I wouldn't mind doing it with another sample of kids to be honest.”
This seemed to be due to the general overseeing being easier than anticipated: it was primarily a matter of prompting that it was an intervention day. “They just needed someone to oversee it to make sure it happened really because if I hadn’t have been here, I don’t think they would have got the clocks out and got the stuff out.” By slight contrast the form tutor was keen to emphasise the importance of a dedicated facilitator during the first few sessions, “think having X here has been a massive help … the first few sessions.”

Both the form tutor and the teaching assistant recognised that some participants needed rather more support and that their approaches to giving this were different, “I’ve nagged them a little bit .. she just bigs them up.” This theme is followed up under ‘engagement’ and ‘self-management’.
One aspect of the facilitation role that was unexpected and more difficult was the need to ring-fence. The teaching assistant felt she needed to protect student time on the intervention. “Time was a big problem and especially if we had things we had to do during form-time.” The teaching assistant’s strategies included prompting students, “getting them organised within the classroom to focus on what they were doing when they’d got to talk to each other about what happened the night before and what was on Coronation Street” and being organised beforehand, “I’d come down here and try and look for the clocks, and try and get it organised.”

The form tutor recognised that this could be difficult given students’ previous experiences, “I think they’re just used to coming in, me moaning at them, and then not having to do a great deal at that time.”

It was also hard for the teaching assistant to protect her own time to run the intervention. “I also have lots of things to do before form, like reading, and things like that. But it worked really well considering what we had to do. .. The biggest thing was the Thursday testing .. which I just forgot.”

Finally, ensuring stop-clock availability could be problematic. “Making sure the stop-clocks were here was a big thing and making sure the stop-clocks worked. .. staff were using them first lesson, so they were already out, so I had to go and gather them up.” Even once the stop-clocks were in the classroom, students had problems with them, “‘Oh yes, stop now’ and then it won’t stop ‘cos the buttons were wobbly” and “If we’d have had say a set that were just specifically for that, that would have been useful, then I could have kept them safe and the batteries charged and things like that.”

**Skill distribution within the social group**

This theme drove much of the feedback. The form tutor and teaching assistant described the girls as mainly bright and motivated with a few exceptions. By contrast the boys were described as generally lower ability and lacking motivation with perhaps one exception. The implications of this are detailed under the next few headings.

**Self-management**

In general, the intervention was felt to be student friendly, in part due to the changes made after the stakeholder group, “it’s fairly straightforward now isn’t it?” and “I think it ran smoothly probably for about 98% of the time”. Students responded well, “They were really organised, putting them back in the right boxes
and making sure they looked after it as well. They weren't just chucking it around or anything.”

The girls were described as totally able to self-manage, “The girls will crack on with it .. There are one or two girls that will struggle but because the rest of them are so strong around it, they sort of push them on” and “girls would give out the booklets and stuff .. they could self-manage, they did it themselves .. I never went to the girls to be honest, very rarely checked the girls.” Rather differently, “The boys needed more motivation … but I think that is just generally those particular boys that are in the form .. it was having somebody overseeing them as well because they were more inclined to just sit there and talk and look like they were working until I came over and interfered in what they were doing .. it was intruding on their little social thing that they have during form-time.” It seemed that girls could integrate social chit-chat with the intervention, whereas the boys found this much more difficult, especially during the earlier sessions.

Also the boys seemed less able to provide each other with reliable feedback, “I said “Have you noticed there’s a mistake?” and they went ”No, no”, or ”How many mistakes did I make?”, ”Oh you made 7”, ”No I didn’t I only made 2”, because they just weren’t that focused on detail.”

**Engagement**

Again this was described as being an approximately boy-girl split. On the whole the girls got on with the intervention tasks and were seen as engaged, “the girls were really self-motivated and organised .. just so involved and engrossed in it”. There were some exceptions, “a couple of the girls who kept wanting to go out and brush their hair and things like that.”

The boys took longer to be drawn in, but most then enjoyed the challenge and competition. “The boys were harder to keep focused”, “I think some of the weaker students put up barriers automatically” and “I think for them they thought it was another lesson .. but once they were stimulated by the encouragement and seeing other people doing it, they thought ”Oh I’ll just do it anyway” .. they liked the challenge of it and the competitiveness between each other.”

Both staff members thought that morning form-time was the best time that could be used for this intervention, “The morning is probably the best slot really .. they’re
tired sometimes but they’ll come in and it’s easy to get them focussed. After lunch .. bit more vociferous if you like.”

However engagement was seen to wane over time and this was attributed at least in part to novelty wearing off before sufficient challenge kicked in, “Most of the lads, even some of the girls have started to say it now “Are we doing this again?”” and “I think they quite enjoyed that challenge .. perhaps we could have bumped it up quicker, .. I think pushing them would have been better.”

**Benefit**

The teaching assistant felt that reaching difficult tasks and having to think about them were important if students were to benefit, and that these aspects had been compromised, “Pushing them to the point where it was like really difficult .. I think being stuck on something is really really good for your brain and everything .. you’ve got to learn how to become unstuck on something and what strategies you’ve gained” and “the communication thing is really important but we were constrained by time and the curriculum”. She also thought the content of the tasks could produce benefit, “I think anything with patterns and sequencing is really good for your brain.”

The form tutor was less optimistic, “Personally mmm.”

Both felt that participants had forgotten the aim of the intervention, “think you explained it quite well at the beginning .. but it was so far away from today .. if you asked them last week, they’d go “Oh it’s just something we’re doing for someone’s research”.”

**Changes**

The teaching assistant suggested a number of changes, specifically ways of implementing that might promote better quality feedback and reflection. She thought a small group would work better, with perhaps some writing, “a smaller group, more organised and they could have kept a diary which said .. I thought this and I did find I achieved the goal”” and “kids keep a little log of what they were feeling when they did it, and if they’ve thought why they were doing it.” Both members of staff thought planned pairings might be better, “we should have done it in here really, to pair the stronger ones up with some of the weaker ones” and “do it with an older student, so they don't both do it, .. like buddy systems with the
reading programme where they come and listen to the kids read of a morning and that works really well with Year 9 & 10s.”

The teaching assistant also suggested ways for more able students to reach an appropriate level of difficulty more quickly, “cut it down to just having an introduction and then getting on to the harder, harder, harder”, and “at the bottom, “if you reach this by Week 2 then move on to Week 6”.”

4.4.2 Feedback from participants
Participant feedback was gathered through four interviews each with a same sex student pair. Using their change in Switch combined scaled score, three students could be described as achieving little or no change (two boys and one girl), three as achieving some change (one boy and two girls) and two as achieving greater change (one boy and one girl).

During the interviews, the boys seemed more able to give their opinions; by contrast most of the girls became quieter than during form-time sessions.

Originally the intention was to analyse the transcripts separately, however initial reading suggested that there were common themes, within which there were some differences of opinion. The same education researcher as previously read through the transcripts and initial codes and was in broad agreement, although suggested that opinion differences should be clearly described within the themes. Checking and resolving at this stage gave inter-rater reliability and allowed the transcripts to be combined for analysis. Member checking took the form of feeding the themes back to the interviewees as a group for comment, before a more general feeding back to the class as a whole. Participants indicated that their views were adequately reflected.

The themes that emerged during discussion were all aspects of usage. This reflects that the interviews were held partly to feedback opinions about using the intervention. Bearing in mind the interview questions, it also suggests the students had little to say about possible intervention benefits.

As the final map indicates, the themes given were considerably interlinked, see Figure 4.14. More detail is provided under theme headings below.

The effort and skills needed
During interviews, the boys were forthcoming about finding tasks difficult, “It was a bit easy and a bit hard; it’s difficult to describe - it seemed kind of easy but got you
confused and was really hard" and the level of effort needed “I would do one task and found it hard to do any more – they were hard" and “Every page it was like, it was getting harder .. I didn't mind it getting harder, but when it got to really hard it was just like dead annoying.” They noticed that they needed to concentrate, “you have to concentrate, 'cos if you're just going along and saying it, like if you had to say like call colours, then it would have like a shape and you would miss it out. .. Not like miss it out, but get it wrong because you were doing all the same thing”, and “you'd be like shape, shape, shape, shape, shape 'cos you just stop concentrating a colour card could come up and you just go, you pass it.” Some girls admitted confusion, they thought because they forgot some rules, “we got confused with the cards 'cos we couldn't remember what the thing was.”

In recognising their difficulties, some students were able to suggest likely general cognitive benefits, “a bit useful because you use it to help you remember and I think it helps your concentration as well.” Others seemed to assume benefits
would accrue just because they had taken part, “it will end up helping us 'cos it all made you cleverer for some reason 'cos you've experienced it.” Still others admitted they were unsure what any benefits might be, “I don't know – I don't really know what it was about.”

**Tasks over time**

The way most students viewed the intervention changed considerably over time. “At the beginning it was fun and stuff 'cos, I don't know, like it was something new to do”, “Like anything really, if you get a new game you play if for a while but it gets boring, and you don’t want to play it” and “It just got boring towards the end. .. and then it was like “I don’t want to do this any more.” ”

This general change in attitude seemed perhaps to be due to this researcher’s decision to choose a few tasks and vary their difficulty, “It was OK but if there was more things different, 'cos then it would make you think again not just, 'cos like every single one was like exactly the same like “in, out, in” and they were like nearly the same.” Varying the response types would have helped, “instead of just having to read out things and write them down.” It seemed that the repetition was particularly noticeable because of the intervention intensity, “I think if it was twice every week or not every morning or something, it would be less repetitive.”

Two boys admitted to a degree of sabotage of the test page, as this was the most repetitive aspect, “I didn't try so hard on it, I may have got worse ‘cos I was bored”, “You see as you didn't like it as much your times got a teeny bit more slow” and “you’d be like, like these shapes, “red, blue” (slowly).”

**Self-management**

Self-managing the intervention seemed to be universally popular, “It was good to do just ourselves .. you could just work through it” and “you gave us instructions and we just got on with it.” Some people felt it promoted better thinking skills, “I'd rather do it myself, do it with a partner just not with teachers, to be honest, ‘cos I learn quicker then. And I find my own strategies of doing it if you get me, like what’s easier.” Some girls stressed the importance of clear instructions, “Like one group on our table would be doing the same thing as we were but they’d be doing the instructions right and we’d be doing it wrong 'cos we've got confused with the instructions 'cos they weren’t clear. .. ‘cos we’d read the instructions differently”. This ambiguity had created some anxiety.
Being able to choose partners was not necessarily seen as the best option if the intervention was to bring benefit, “I’d probably prefer being with a mate but whether it depends on like doing me best”, “I wouldn’t mind being paired up. It could work better if you were paired up” and “I’d probably concentrate a bit more.” However it was important to be in a same sex pair, “Yeah, boys and girls in our form don’t talk. .. So if I got put with a girl, it would be a bit more awkward because I don’t talk to the girls in the form”, “I can’t talk with girls, so it wouldn’t work with a girl, I wouldn’t say anything” and “If you got put with a boy or something then you wouldn’t really speak to them.” Also, being comfortable was important, “Say I was trying to do my best, I would be more comfortable making a mistake in front of my mate than making a mistake in front of someone I don’t know, who’s better than me.”

Form-time

Students gave their views on having the intervention trial in form-time. The more dominant view seemed to be that form-time is a recognised prelude to the day that should be different from lessons, “form’s usually like a set off, everyone talks .. so it (having the intervention) goes like different from talking all the time, to like having to do this every morning, so everyone’s like used to not doing anything in the morning so it’s like a bit of a change, like actually doing work if you get me”. It is a time when they should be able to talk to friends, “If it was every morning I’d get a bit bored. .. ‘Cos then I wouldn’t be speaking to any of my mates or anything.” However there was another view, “I liked just getting on with it”, “It was OK in form-time, better than what we normally do.”

Those who felt form-time should be a recognised prelude also suggested that later in the day would be a better intervention time. “I’m always tired in form ‘cos you’ve just got up. ‘Cos it’s dead early in the morning. .. especially on a Monday”, “at break when you’ve had two lessons so you can think a bit more, your brain will be working a bit more” and “or if you pulled us out of lesson or something ‘cos we’d probably be in a better mood. .. We would be thinking in lesson. .. we would be in the mood of learning.”

Two students suggested substituting lessons they don’t enjoy with the intervention, “it could be for a whole hour in English – that’s really boring!”
### 4.4.2.3 The researcher’s diary findings

The diary content that seems most obviously to be worth explicit reporting was that collected instead of observations and some additional unanticipated feedback offered by students during the retesting. Some of this has already been integrated into the classroom diagram.

The ‘observation’ information is given in themes in Table 4.5 below. Although the diary provides some additional detail and interpretation, the themes are mainly in line with the other qualitative information already reported. One additional theme is the concern over missed sessions and how to respond to this, see dosage and logistics.

Turning to the feedback, 16 of the 22 students offered brief comments. 5 said that they found the tasks OK or enjoyable throughout, 3 said they found the tasks alright at first but then too repetitive, 3 said some tasks were hard and mixed you up, 2 said that having the intervention in form-time was fine but not every day, 2 said it was boring, 2 said the intensity needed to be reduced or the variety increased and 1 said it should have become harder faster. Again, this feedback is in line with the views given through interview, suggesting in turn that the interviews provided a good reflection of general student opinion.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Information</th>
<th>Intervention week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosage and logistics</td>
<td>Asked to run the intervention, to release TA.</td>
<td>1, 3, 6</td>
</tr>
<tr>
<td></td>
<td>No intervention – class off normal timetable. Should alternative participants be sought?</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No observation this week as class out on a trip; discovered this once in school. TA decided to use PSHE to make up time, but afterwards mailed feeling despondent. One hour was too long to spend on activities designed for short bursts and students became restless – last thing Friday pm.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Sessions missed were all predictable, except strike, so why not inform – is this just part of implementation issues?</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Had considered pulling out because of missed sessions – though not said to school staff. Decided not to after additional time given in PSHE. Offered to assist with intervention to boost TA morale.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Changed observation to ‘test’ day, to fit around strike. Realised time-series data not collected and/or not accurate in many cases.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Form tutor and TA offer additional week of intervention after Easter to make up lost time. Declined: not seem fair on students or in line with ethics.</td>
<td>5</td>
</tr>
<tr>
<td>Materials</td>
<td>Stop-clocks don’t work well: unreliable buttons, poor charge and availability.</td>
<td>1, 3, 4, 5, 6</td>
</tr>
<tr>
<td></td>
<td>Materials mistakes: task rule card contains an error.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Materials confusions: ‘Test’ and Task A look similar because they are the same, and this is confusing to students. Tasks on sheets look similar at a glance, so sometimes on wrong one.</td>
<td>4</td>
</tr>
<tr>
<td>Theme</td>
<td>Information</td>
<td>Intervention week</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Engagement (Seems to reflect a journey at different rates, perhaps as should have expected.)</td>
<td>Students seem to understand what to do and to be getting on – except four. Two fine after encouragement. Getting into pairs or threes seems to have worked out. Some saying having activity to get on with, with friend, is better than sitting doing nothing.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Apparent engagement levels mixed – see classroom diagram. Pockets of better engagement/self-management; pockets of heavier TA support; pockets of quiet non-engagement.</td>
<td>3, 5</td>
</tr>
<tr>
<td></td>
<td>Boys reported to particularly not like doing intervention in PSHE, ie for a whole hour. Some girls liked as had chance to move to harder tasks – not enough have had this experience?</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Noticing boys (because mainly with boys) not always Shifting and they are not noticing. Wondering how much in-depth engagement – and is this particular to the intervention</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Students are losing sense of what the intervention is about and life relevance; some have asked – girls and boys. This needs to be built into the metacognitive discussion, with facilitation.</td>
<td>5, 6</td>
</tr>
<tr>
<td></td>
<td>Felt intervention ‘used’ to get at two boys who were not behaving in core lessons; the suggestion to get on was forcefully made. I felt I had to then go and repair with positive support. (Also queried with staff.)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Facilitating small groups successively had big effect. - Girls wanted me to join in and this then gave new enthusiasm as I made mistakes. Some were struggling - now on hard tasks that making them feel exposed, because they know they are making errors. - Boys as a group feeling more OK than at any point: self-managing and engaged. - Whole class seemed happier and the atmosphere felt more positive. Makes me think that it could work in a class, with more informed/focussed facilitation – this would help to stimulate conversation and increase perception of relevance: requires a culture change from ‘get on and do’.</td>
<td>6</td>
</tr>
<tr>
<td>Facilitation</td>
<td>TA is maximising time students engage with tasks by running around giving out materials. Does this creates dependency rather than self-management?</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Would small group give better data and social mediation of metacognition? Whole class is harder to facilitate well: - students want to self-manage, form-time is messy and metacognitive discussion is not happening as expected (compared with pilot work). Latter partly due to nagging to ‘get on’? – smaller group easier to enthuse? When in, I try to do, table by table and it provokes discussion – if did as a whole class, then majority of engagement time would disappear since there is only a short time when all students concurrently available.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Should I have spent more time training the TA, either explicitly or implicitly by co-running more sessions. Very conscious that cannot seem critical – am so grateful to have host at all.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Should I have run intervention all the way through? Increasingly realising that some intended aspects have been effectively removed or at least substantially reduced because of implementation circumstances – specifically the talking around why errors occur and why some tasks harder and what strategies students use/develop.</td>
<td>5, 6</td>
</tr>
</tbody>
</table>
Chapter 5  Discussion and conclusions

5.1 Chapter outline and aims
The discussion is split into four main sections. Each of the first three addresses the research question used as its title and starts with a summary of the pertinent results before attempting to evaluate those outcomes. The fourth section provides an integrative summary including suggestions for the main study implications and final conclusions. Much of the discussion was derived from a Content Analysis of the researcher’s diary.

5.2 RQ1: How could a prototype Shift intervention with sound theoretical underpinnings be developed for young adolescents?
This section covers the development process up to the point a pre-prototype had been created.

5.2.1 Summary of results
From previous work, this researcher already had a pragmatic rationale for the study. EF has important associations throughout the life span (including academic performance), some groups are more vulnerable to poorer EF and EF intervention research is a relatively undeveloped area with mixed/limited useful results to date.

Moving forward, theoretical underpinnings were built through an exploratory process: engagement with the literature and two structured discussions with EF experts. The questions addressed purely through engaging with the literature were perhaps the most fundamental:

i) are general cognitive functions theoretically amenable to intervention (and specifically within adolescence), and

ii) is the chosen model of EF robust?

The issues discussed with the experts were more practically urgent:

iii) what is meant in detail by the skill Shift and how does it interact with and/or sit alongside other skills within EF?

The resolutions achieved (see i to iii below) allowed for the creation of theoretical models that in turn suggested potential mechanisms of benefit within an intervention.

i) Regarding the debate on whether neuroscience findings should be applied to education, the conclusion was yes, but with caution. Researchers creating the
applications need to be able to bridge gaps in perspective between neuroscientists and educators so that neuromyths and unrealistic expectations are less likely to be generated (e.g. Anderson & Reid, 2009; Geake, 2008; Howard-Jones, 2014, 2008; Mason, 2009). Equally these researchers must provide robust applied evidence of day-to-day benefit (Apter, 2012; Melby-Lervåg & Hulme, 2013). This takes time and to date EF intervention research has yielded limited ‘far’ effects. However, the field currently seems too embryonic to allow definitive conclusions (negative or otherwise) (Gathercole, Dunning, & Holmes, 2012; Howard-Jones, 2014) and Educational Psychologists are well placed to contribute, through their ability to interpret academic findings combined with their day-to-day experience of varied educational environments.

More specifically, adolescence would seem to be a natural opportunity to intervene with EF (e.g. Greenberg & Rhoades, 2008; Pokhrel et al., 2013). In early adolescence it appears to be typically sufficiently fractionated for the three components (Miyake et al., 2000) to be identifiable (e.g. Duan et al., 2010) but not yet developed to adult capacity (e.g. Best et al., 2009). This cognitive development is mirrored by adolescent brain plasticity and environmental sensitivity. These are particularly evident in prefrontal cortex, the principal substrate for EF and its evolving connections (e.g. Bryck & Fisher, 2011; Chein and Schneider, 2012).

To complete her theoretical rationale for intervention, this author investigated the statistical concept heritability to discover that high EF heritability does not preclude intervention (Miyake & Friedman, 2012). Rather, proportionately high genetic contribution suggests also proportionately high shared relevant experience (Asbury & Plomin, 2014).

ii) A recent critique (Willoughby et al., 2014) of the methods and assumptions used by Miyake and colleagues (Miyake et al., 2000) to produce the three component model threatened to undermine its use. However, although this researcher concluded that the tasks chosen may have affected the resulting model, for now the criticisms are not sufficiently strong to reject it. Equally, evidence accumulates for the utility of the three components (e.g. Best et al., 2009).
iii) A more developed understanding of Shift was achieved through examining the Shift task paradigm (e.g. Huizinga & van der Molen, 2011; Waszak et al., 2003) and re-considering how EF links with other control accounts, such as the Central Executive (Baddeley, 2012). An incomplete synthesis of this was presented to the first expert group.

Here, discussion allowed ideas to start to crystallise, with some coherence building around what an intervention focussing on Shift would be trying to achieve in the context of (a) accepting that EF has limited capacity and that (b) the intervention was to target adolescents who have existing Shift skill. Shift development became defined here as both the increased ability to change mind-set and the improved ability to coordinate this with Working Memory and Inhibition, with some bootstrapping between the three. Shift task difficulty could then be defined both by Shift difficulty per se and by total EF load. Hence, it was the discussion itself that began to answer the interview questions and to enable the researcher to then re-develop a task matrix within which Shift tasks could be placed according to their level of difficulty for each of the three core EF components, see Figure 4.3, and therefore also total EF requirement. Additional tasks could later be identified and/or developed to fill empty matrix cells as necessary.

The first expert group also looked beyond the particular EF model to suggest other design considerations. These included using paired working to create short, intense and distributed engagements with tasks, checking the non-executive skill requirements of tasks, such as naming colours and shapes, and incorporating aims from the Learning Hierarchy: reduction of errors, an increase in fluency and the provision of feedback. Paired working would also contribute here, by providing a means for feedback which should in turn promote metacognitive reflection. Marshalling metacognition was offered as an essential ingredient/mechanism for improving cognitive skill.

Discussion in the second expert group served to confirm that the intervention now appeared to have a framework providing logical ways to vary task difficulty and to produce benefit. This assumed, the discussion took a somewhat more practical turn: the translation of the matrix into a concrete intervention. Specifically, it was

---

1 Exploration had been steered by experimental results that appeared to imply that all EF skills draw on a limited common capacity (Davidson et al., 2006).
suggested that tasks be chosen so that they could reappear in different parts of the matrix and hence at different difficulty levels. This might provoke additional metacognitive reflection, provide the sense of achievement necessary for sustained motivation and support efficient self-management in the short time slots available.

Moving beyond its intended remit, the second expert group also provided reassurance that the inevitable uncertainties in work of this kind were being resolved positively.

With this overall endorsement a first version prototype intervention was then developed. To reiterate, this was underpinned by a theoretical rationale for intervening with adolescent EF, by a model of EF that was created through combining two existing models (Baddeley, 2012; Miyake et al., 2000) see Figure 5.1 and by a task matrix (see Figure 4.3 and Table A4.2) covering a range of Shift difficulty and EF demand overall. The modified model of EF proposes EF to have limited capacity within which increasingly separable but better coordinated component skills develop. Mechanisms for improving Shift skill were thus implied to be engagement with tasks of increasing Shift difficulty and engagement with tasks that require increasing coordination of all EF skills, perhaps pushing at the limits of overall capacity.

Specific design considerations gleaned from previous work and literature outside of the EF field would promote additional beneficial mechanisms. These included short intense bursts of practice, feedback and socially mediated metacognitive reflection. Students would work in pairs, alternating between being the person 'having a go' and the one monitoring fluency (timing and watching for errors).

5.2.2 Critique of the theoretical development results

This critique addresses Research Question 1 with reference to the theoretical developments.

Before this it is seems worth briefly suggesting how the associated methods could have been made more robust. Essentially the idea of convening expert groups to guide development work seems sound: it produced results that were useful within the later stages of the study. However, a broadening of the technique would have been beneficial, both in terms of including a greater variety of perspective within the group (including greater scepticism) and making sure that all developments
were subject to expert scrutiny, including the more theoretically fundamental aspects. This would have helped to avoid some likely bias: this researcher was unlikely to conclusively doubt the possibility of intervention since this would have called the entire study into question.

**Figure 5.1: Copy of the proposed model of Working Memory**
(This is a copy of Figure 2.3.)

Putting aside this flaw, it should be remembered that the theoretical rationale and underpinning were created in part to address this researcher’s own lingering concerns and as well as to create a defence of attempting EF intervention. To the extent that she was able to grapple with and synthesize the literature appropriately, this researcher has no reason as yet to doubt her conclusion that adolescent EF is theoretically amenable to intervention. In addition, it was useful
to be alerted to the need for applied research to bridge different perspectives and

As for the EF model being used, the three components (Miyake et al., 2000) had
already been adopted for pragmatic reasons. However, there are other versions
of the truth available could probably have been developed and used to equal
effect, for example a more attention-based fractionation of EF (e.g. Baddeley,
2012; Garon et al., 2008). However, this researcher believes the experts
supporting her provided an informed sounding board: they would have challenged
a poor choice at this stage. Therefore the presented three component version of
the truth is probably as valid as any other and it brought the benefit of numerous
associated and tried activities, most notably many variations of the Shift/-/Switch-
task paradigm.

A direct approach to intervention had been chosen prior to the start of this study.
The programme tasks therefore were determined by their known/likely focus on
Shift and EF more generally. Further choices were made to exclusively include
tasks of the kind found in experimental research, this precedent having been set
(Röthlisberger et al., 2012) and to limit the number used, as recommended by the
experts. This type of task was also compatible with short intense bursts of
engagement and the need to fit flexibly into a short time slot. However, these
decisions arguably ignored earlier findings highlighting the importance of task
novelty and the opportunity to exercise some creativity (Darby, 2013b). This point
will be picked up again later in the final section. More positively, the use of
experimental tasks made it easier to place them relative to each other within the
proposed task grid and also to develop versions that could plausibly occupy empty
grid cells, without an extensive task testing that would have been beyond the
possibilities of this research. They were known also to draw on limited, specifiable
non-executive skills, such as shape and colour naming.

Had an indirect approach been chosen instead, it could equally have drawn on an
accumulating evidence base (Diamond, 2012, 2013), with the intervention taking
the form of say a martial arts programme. This would likely have impacted on EF
as a whole, with a specific component focus being difficult to achieve. Instead,
repeated measures of core component skills might have constituted evidence of
their mediational value (Riggs et al., 2006). The theoretical rationale and
underpinnings would have pertained equally and metacognitive reflection may
again have been a proposed crucial process. One advantage of such an indirect approach might have been greater appeal to at least some adolescents. However, as indirect approaches tend to be dispensed in larger or pervasive doses (Greenberg, 2014), recruiting a host school (Darby, 2013a) and offering the appropriate support may have been a struggle.

Given the research field, any approach could have contributed to the evolving evidence base. The chosen specific and direct approach had a particular research novelty (Shift focus) and was realistic within the resources and participant access available.

As the development work progressed, this researcher believes that the results inevitably became increasingly idiosyncratic. Even with the same underlying EF model and an intention to focus on Shift using experimental tasks, another researcher would likely have created a rather different pre-prototype. For example, a different taxonomy of core component dimensions into discreet difficulty levels would have led to a different systematic task matrix. Equally, the tasks could have been differently placed into the matrix. Here it was through the judgement of this researcher, with no additional verification. The second expert group gave permission for this at some level by designating the researcher the expert in her matrix. Nevertheless there should arguably have been some external checking.

Overall then, by the time a well-populated matrix had been developed, the journey past several decision points had resulted in this particular instance, but an instance that had a robust theoretical rationale and indicated plausible mechanisms of benefit.

Hence, looking to Research Question 1, one way that a prototype Shift intervention with sound theoretical underpinnings could be developed for young adolescents is through the described processes of exploration and decision making. Here, these led to a new model of EF, an explicit conceptualisation of EF development, a taxonomy of typical Shift task difficulty along the three component dimensions and hence a populated matrix structure, or pre-prototype that can provide a basis for prototype development.

5.2.3 Implications of the theoretical development work
In this study, the first step in the development of a prototype package designed to intervene with adolescent EF (focussing on Shift) was the creation of a theoretical
rationale. This author believes that the material thus engaged with is typically not presented within the predominantly pragmatic introductions that precede intervention accounts. To the extent that she has been able to grapple with and synthesize the literature appropriately to reach valid conclusions, this researcher therefore also believes she has gone some way to create a theoretical legacy that can underpin any EF intervention for adolescents and regardless of the fortunes of the particular package offered here. It supports assertions based on practical evidence that EF can be a legitimate intervention focus (Diamond, 2013) and also Greenberg and Rhoades’ (2008) call for adolescents to receive EF research attention and Zinke et al.’s (2012) attempt to extend EF intervention to this age group. Nevertheless, it requires due scrutiny by those who are sceptical (Apter, 2012; Melby-Lervåg & Hulme, 2013).

A second and perhaps enduring contribution is the theoretical marrying of EF and Working Memory, within a modified version of Baddeley’s working memory model (2012). The thinking that led to this is not new (Baddeley, 2012) although the provision of a model perhaps gives it additional substance. Creating the explicit link in this concrete way provides a more obvious target for necessary peer scrutiny.

Expected criticisms include the use of the earlier Miyake model (2000) without sufficient regard to the later one (Miyake & Friedman, 2012), or indeed to alternative attention-based fractionations (Garon et al., 2008). In response to this and in line with Critical Realism, this researcher would argue that it is important to name the lens through which one sees the world (or in this case EF), since a particular perspective inevitably avoids and/or loses insights that other lenses could have provided. Yet a lens must be chosen for any progress to be made. A useful future piece of work might be to compare two or more EF fractionation discourses and evaluate their likely common reality. Again this would not be new thinking, for example Korkman et al. (2007a) already place attention, Inhibition and Shift skills within the same domain. Rather it would make the similarities and differences more explicit. More broadly, in depth study comparing core component models of EF with other conceptualisations (see Appendix 2.1) could be useful, such as those focussing on higher level planning processes and metacognition.
Further anticipated criticisms of the presented model link to the proposed intervention benefit mechanism, metacognitive reflection (Fisher, 2007; Hattie, 2009; Stel & Veenan, 2010). It is not clear how the core components are related to it. In reducing EF to three basic processes, arguably one loses sight of the sophisticated processing composites, such as metacognition, that they must support in order for EF to be the “superordinate, managerial capacity for directing more modular activities, including language, memory, motor skills and perception in the service of setting, managing and attaining goals” (Levin & Hanten, 2005, pg. 79). Perhaps the improved coordination of existing component skill now suggested to be the main EF development during adolescence is in fact the basis for metacognitive development at this time, with again bootstrapping within a Central Executive of limited, but increasing capacity (Davidson et al., 2006; Garon et al., 2008). This has yet to be worked out.

There are two additional expected criticisms of the presented model. Firstly, there is obvious and previously referred to potential for confusion between Working Memory, i.e. Updating as a core EF component (Miyake et al., 2000; Miyake & Friedman, 2012) within a Central Executive, and Working Memory the broader concept that includes the Central Executive (Baddeley, 2012). Secondly, the model’s EF components may be too much defined by their outcomes (Morton, 2010, 2014), although the work by Herd et al. (2014) forms some protection by showing that component-like behaviours can be produced with neural network simulations.

Now looking further on, if one can accept the presented EF model, it allows the proposal of systematic mechanisms to produce benefit within an intervention. To reiterate: a) Shift skills themselves could be stretched and developed, but also b) EF as a whole could be challenged by loading requirements for all three components. Again, this is not new (Davidson et al., 2006), but the presented task matrix extends the work done previously. It provides a rationale for task generation that is in stark contrast to the random collation of tasks in earlier work (Darby, 2013a,b). Nevertheless, the matrix should be treated with some caution until other researchers lend it support; the difficulty levels were derived from detailed study of the Shift task paradigm, but are this researcher’s synthesis only.

The particular tasks inserted into the matrix were harvested from Shift literature and chosen for their brevity because of the known research environment. With
more time others could be developed that embody the same skill levels, but with greater likely appeal to adolescents.

An important benefit which this researcher derived from her engagement with the literature was a more extensive knowledge base than she would probably have acquired otherwise. This has already been useful with fieldwork placement casework. It has allowed the recognition of EF difficulty in children who fall into one or more vulnerable groupings, for example brain injured or born significantly pre-term. This in turn has allowed (a) other skills to be pinpointed and highlighted, (b) useful explanations to be given and (c) whole school awareness of EF to be raised.

5.3 RQ2: How might such a Shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?

This section covers the creation of the specific prototype intervention, starting with a first version taken to the stakeholder group. It then explores how well the prototype (developed after the stakeholder group) fared in terms of running smoothly in the applied research environment, taking into account all perspectives.

5.3.1 Summary of results

The limited number of first version prototype tasks produced for the stakeholder group was created directly from the populated task matrix. The overall form of the intervention was guided by other ideas, from both additional literature areas and expert group discussion, see Figure 4.5. Students were to work in pairs and guide themselves through the levels of difficulty, using a booklet that suggested a task order and contained spaces for creating written feedback.

In more detail, specific features/ideas included were as follows:

Learning Hierarchy. (i) Task analysis had allowed tasks to be placed in the matrix and ensured that they did not draw extensively on non-executive skills: they primarily required the naming or reading of simple shapes, colours, single digits and single letters. (ii) Fluency and feedback. Students were to be encouraged to improve their fluency through reduction in time taken and errors made on a task, the latter taking initial precedence. They were to record feedback provided by their partner (time taken and number of errors) to produce evidence of progress. (iii) By taking turns during the thrice weekly sessions, students would be engaged in distributed practice. (iv) Interleaving was introduced by requesting that a ‘test’
task be visited each week, that would also generate time series data. It was hoped this would engender a greater sense of progress as it became relatively easier. Also students were free to tackle tasks in any order.

**Flow** likelihood was promoted through giving students control through self-management, allowing students to seek their own level and providing challenge that would promote full engagement.

**Cooperative Learning and Social Mediation** were promoted through paired working. This had already been successful previously (Darby 2013b). It would hopefully promote modelling opportunities, vicarious learning, reciprocal teaching and discussion containing metacognitive reflection.

**Comic Strip Conversations.** Simple figure drawings were to be used to suggest how metacognitive conversations might arise in reaction to student observations as they progressed through the tasks.

Other features built in included having short tasks taking typically a minute or less each, to give flexibility in terms of the number of tasks that could be used per session. Also there was a limited number of tasks to be learned. As suggested in the second expert group, the tasks reappeared at various difficulty levels, so that students could move through the booklet efficiently and notice skill requirement differences.

Following their group discussion, it was clear that at this point stakeholders were preoccupied with avoiding chaos and were keen therefore that intervention changes should support smooth student self-management as far as possible. In response, a single student booklet was retained but changed to A4 format (from A5), a visual 1:1 correspondence was created between each task appearing in the booklet and the materials needed for it and many of the comic strip-like illustrations were removed to de-clutter.

Confidence for the intended main facilitator, the teaching assistant, was increased substantially through a short (20 minute) trial of an amended prototype with pairs of Year 7 students. This researcher used the session to provide some training through modelling facilitation. Afterwards, the teaching assistant was keen to start using the intervention with the planned Year 8 form and with no further training.
The full prototype was then created. Variations of the ten base tasks were developed to fill all of the matrix cells. These were produced onto laminated sheets or cards. A guiding booklet was printed for each student and the facilitator.

During feedback, the teaching assistant reflected that the intervention had run more smoothly than she’d expected. Her role had been less about helping students to access the materials but instead more about making sure that the time and resources were available as intended. This protective boundarying was needed to ensure she could run the intervention despite other duties and to ensure students would engage with tasks, despite also using form-time for social purposes. So long as the materials were out, the majority of girls self-managed independently and supported each other, whereas the boys required more adult support. The teaching assistant also needed to ensure the stop clocks were available and in sufficient working order. Sometimes this had meant retrieving them from other staff members who had them ready for the first lesson.

The form tutor had rarely been involved, except occasionally to suggest that particular boys engage more seriously. Instead he had continued to carry out the usual form administration. However, he noticed that by the end of the intervention period, the girls were losing interest. Looking at the teaching assistant's perspective on this, she felt that the boys' interest had gradually picked up, as they were drawn in by a competitive element. For all students, including the girls, she wondered if the laterwaning interest could have been supported through reaching challenging material sooner. This was one of the changes suggested.

Other suggested changes primarily focussed on promoting better feedback and reflective discussion between students. The teaching assistant appeared to be suggesting that these elements had been less successful and that in turn the impact of the intervention may well have been undermined.

Both staff members felt that form-time was the best time slot for the intervention, as they thought students would be more focussed than later in the day.

Feedback from the students indicated a general feeling\(^2\) that at first the intervention had engaged them through novelty, but that it contained too few base tasks to maintain their interest over time, particularly as they were using them

\(^2\) The consensus of opinion would suggest that combining student feedback data was an appropriate decision.
several times each week. There was also consensus that self-managing the intervention was a positive aspect, although there were mixed feelings about who they should work with. Engagement might be improved if staff imposed the student pairings, but students would feel less comfortable making mistakes and in this form mixed-sex pairings would preclude any useful discussion. As the intervention was in form-time, it was important to still be able to talk to friends. Indeed the majority view seemed to be that form-time must be preserved as different from the rest of the day, a chance to settle into school. Linked to this, the majority of feedback suggested that students would be more alert later on and more in a frame of mind for learning. Nevertheless there was a minority view that to have an activity in form-time was preferable to the usual lack of structure.

Entries in the researcher's diary indicate a degree of anxiety over dosage and lack of reflective discussion. Intervention sessions had been cancelled, mainly because of clashes with other school activities. The teaching assistant's attempt to make up time during an hour of PSHE time one Friday afternoon had had mixed results. Several students had been restless, although some had used the opportunity to move ahead through the booklet.

Metacognitive reflection had been deemed an essential socially mediated mechanism of benefit. However in form-time, tasks were fitted in between conversations having a social focus. Conversation addressing the intervention had been encouraged with the boys, but more rarely with the girls. However, when it was, it appeared to promote engagement. How to effectively facilitate this within whole class messy form-time was an issue that would be difficult to resolve.

The researcher's diary also reflected participant feedback that the intervention was not difficult to self-manage and that finding a partner or a two to work with had not presented a problem. In addition, it picked up similar patterns of differing engagement levels, with most girls quietly self-managing alongside chatting, some girls quickly finding ways to not engage (leaving the classroom on errands) and most boys requiring greater support to appear to be engaged and to provide effective feedback to each other. This support seemed to have encouraged the boys to become more involved over time.

The diary also picked up the stop clock problems and some minor presentation issues within the intervention.
5.3.2 Critique of the practical development and implementation

This critique addresses Research Question 2 with reference to the practical developments and the implementation.

Visiting the associated methods briefly first, both the session observations and the facilitator training could perhaps have been more effectively planned by anticipating the need to be creatively responsive to the unfolding intervention situation. A suitable repertoire of potential techniques and materials could have been generated and then used selectively as appropriate and perhaps as indicated by regular proactively sought brief feedback from the facilitating teaching assistant. This might have created a more timely awareness of the teaching assistant’s training needs, see below for more discussion, as well as a more empowered approach to observations. For example an additional member of staff could have been trained to fill in the observation grids, thus releasing this researcher to plan/execute more effective support.

Turning now to the practical developments, the exact appearance of the prototype intervention package inevitably required some informed decision making on the part of the researcher. Decisions were based on multiple sources: expert suggestions (number of base tasks), stakeholder feedback (booklet de-cluttering, instruction location and single versus multiple booklets) and existing research within the EF field (e.g. Diamond, 2012; Röthlisberger et al., 2012) and without (e.g. Moneta and Csikszentmihalyi (1996) on Flow, Martens and Eckert (2007) on distributed practice and Hutchins and Prelock (2006) on comic strip conversations). Therefore despite decision making being based on research where possible, as more decisions were made, the prototype inevitably became just one of an increasing myriad of possibilities.

Given the background literature, one obvious alternative would have been a computer-based intervention. This would give reliable feedback and provide tasks at the right level automatically, rather than relying on student self-management, with some prompting from a facilitator. However, it would lose the social mediation deliberately designed in through paired working to try to provoke metacognitive reflection through discussion.

A small group intervention could have been another alternative. This would have changed the facilitator role and perhaps given opportunities for more managed...
whole group discussion. In this study, intervention self-management was in part a pragmatic decision to deal with context: a whole class trial in form-time.

Overall, this researcher believes that many of the features of the intervention were appropriately planned and that drawing on a wide literature was useful. However, the prototype was then incorrectly legitimised by the short ‘play test’ with Year 7 pupils. Their ability to navigate through it did provide some necessary ‘worst case’ reassurance to the teaching assistant. The group was younger than the research participants and made up of on average less academically able students. However their keen engagement over a short period should not have been taken as an indication of suitable initial difficulty level for a whole class of Year 8 students likely covering the full ability range. A ‘play test’ with Year 8s may have reached different conclusions.

Looking at how the prototype then fared in the evaluation, it seems that feedback from the stakeholder focus group had served its implied purpose. It had prompted design changes that would ensure chaos did not ensue. The different perspectives (student, facilitator and researcher) appear to concur over the intervention ‘working’ in the sense that it could be fitted into the time slots available, that students could negotiate their own way through it, find the resources they needed using the visual labels and then also pack it away easily and quickly.

In interpreting how smoothly the intervention ran, it seems important to differentiate between efficient self-management and effective engagement. As indicated above, all students seemed able to self-manage the intervention to a degree, but their styles and levels of engagement varied considerably.

One sizeable sub-group of girls efficiently and methodically self-managed themselves through the booklet, reportedly requiring little facilitator attention. They interspersed this with the usual social chatter of form-time. This researcher believes that this juggling had consequences. The girls plodded conscientiously, but unthinkingly, through the tasks in order rather than choosing from the appropriate and perhaps more difficult levels. When the same task appeared at different levels, they rarely explored the requirement differences through discussion, as their conversation tended to revert immediately to social content once a task had been completed. It is perhaps not surprising then that they
started to find the intervention tedious. Equally, this researcher would argue that "not again" was a comment not just about the intervention itself; it also referred to further intrusion into form-time. However, when this group belatedly received facilitation, they responded well and seemed keen to discuss their experiences of current tasks.

A smaller second group of girls showed a different pattern of engagement. They efficiently brought the materials they needed to their table, but then all but one\(^3\) would find reasons to leave the classroom at least once. As they created no disturbance they were rarely challenged, but their engagement was low.

By contrast, with a few exceptions, the boys required encouragement to self-manage and so they attracted attention and hence facilitation. The teaching assistant noticed how the feedback within the pairs was not reliable and in discussing this she promoted some metacognitive discussion. Over time, the boys’ engagement increased and they enjoyed the competitive element set up by the teaching assistant. Nevertheless, by the end they too had had enough.

This description of the differing styles of engagement is also a description of differing facilitation. In evaluating whether or not the intervention ran smoothly in a secondary setting, it is important to establish not only that it ran in an orderly fashion, but that it ran fruitfully in a way that preserved critical mechanisms of benefit. By carrying out the tasks as instructed the students would have been exposed to increasing Shift difficulty and the need to juggle the three core components within a limited Central Executive. However, their engagement in metacognitive reflection through discussion had also been suggested as a critical mechanism, in the sense of maximising benefit through understanding the skills involved. In responding to the request to de-clutter the booklet, this researcher had removed most of the built-in prompts for discussion and had created a reliance on spontaneous discussion, as had arisen in earlier work (Darby, 2013b) and on facilitated discussion. This author would argue that to expect spontaneous discussion was unrealistic. In this implementation the intervention was running alongside social chattering and not within dedicated time and the participants felt more exposed in this whole form setting where they talked only within particular

---

\(^3\) This particular girl was part of the minority view that having an activity in form-time was an improvement. She worked alone for the majority of the sessions.
groupings. The described pattern of facilitation therefore assumes greater importance.

The boys were more strongly supported and the teaching assistant facilitated metacognitive discussion; they were gradually drawn in and their engagement improved (until near the end). By contrast the girls largely self-managed and lost interest, until this researcher realised they were getting despondent. The incidental need to run the intervention provided the researcher with useful opportunities to facilitate metacognitive discussion with them in small groups. The positive effect this had on engagement was perhaps the more noticeable for taking place at a time when enthusiasm was waning. That at least some metacognitive reflection had taken place by the end of the intervention was evident in student feedback, “you’d be like shape, shape, shape, shape, shape ’cos you just stop concentrating a colour card could come up and you just go, you pass it.”

Overall then, the prototype intervention could be said to have run with some smoothness in terms of orderly self-management. This allowed a confidence to build regarding classroom viability as well as a basic engagement with tasks at differing Shift difficulty levels and with different requirements to juggle the three core components within a limited Central Executive. However, with limited deliberate facilitation the specific implementation lost much of the metacognitive reflection that had been suggested to be important. In so doing, there is risk that the intervention as a whole runs the risk of being labelled a brain-training programme, perhaps particularly because of its abstract appearance.

By the end of the intervention, the teaching assistant had become aware of the importance of discussion and knew that her role needed to be more than programme administrator. Lost opportunities for this researcher to observe were also lost opportunities for discussion around training. Arguably the teaching assistant’s initial focus on orderly administration was entirely appropriate and she had rightly concluded that she needed no training for this. Over time through facilitating the boys’ engagement, she had become aware of the need to reflect on the activities. At some point during this process, it would have been appropriate to give explicit training around the importance of metacognitive discussion and also impart the language of EF so that this could be passed on.

---

4 This despite the underlying rationale and precedence for task choice.
Some additional comments regarding facilitation and training seem worth making. Firstly, within this particular implementation, facilitation needed to be for small groups. The form dynamics would have made whole class discussion difficult and in form-time there were few opportunities to engage all students at once without disrupting the form tutor’s management tasks.

Secondly, training for the teaching assistant could have involved further modelling or separate dedicated sessions. Both would have required additional researcher time that had not been planned in. Modelling within sessions would have pushed the implementation more towards being an efficacy trial (Greenberg et al., 2005) and this would have detracted from any later conclusions regarding robustness in a typical context. These are arguably essential for wider school take-up.

Thirdly, facilitation of discussion may have been particularly necessary with the tasks chosen. Their abstract content may have made it harder for students to find ways to talk about them and feedback quotes provide some evidence of this, “It was a bit easy and a bit hard; it’s difficult to describe”. Initially, the students had accepted on trust the idea there might be “thinking skills” benefits, but they lost any sense of what the intervention was about. Provision of EF vocabulary may have supported students’ discussion and understanding and in turn allowed better noticing of skill requirements within later tasks. Knowing what to look out for may have allowed students to find the intervention tasks interesting for longer and reduced stress when making mistakes and may even have eventually provoked non-facilitated reflective discussion in small groups.

Even if engagement could be improved in this way, the feedback from students suggested that the inclusion of more different tasks would have helped to keep the novelty for longer. As they self-managed the current prototype intervention without difficulty, this would be unlikely to significantly impact on orderliness. To fit with the matrix rationale, new tasks would need to appear superficially different, but embody the same skill mixes.

Also it would still be important to ensure that students move quickly to tasks at a level of difficulty that feels right for them, as they would likely not have the insight

5 This was during the whole class introductions given by the researcher during form-time, which described EF skills. As with the teaching assistant, this was not the time to absorb such information.
to do this in the early stages. How this would work out within friendship-based paired working is difficult to imagine, since it would require pair members to be well matched on EF skill if they were to provide each other with effective feedback. The teaching assistant’s suggestion of introducing older mentors could be sensitively explored.

In addition, all the sources of qualitative feedback imply that the ringfencing achieved short term would not be sustainable over time. In this setting, most students want social form-time and it is difficult for facilitators to juggle other job requirements with looking for equipment and facilitating the intervention. Although, these are considerations specific to this implementation they may well pertain elsewhere, as form-time is an obvious place to squeeze in additional activity without disruption to the rest of the curriculum. Recruiting students who will not contribute to school performance targets could be an easier way to build the evidence base.

Hence, looking to Research Question 2, one way that a Shift intervention for adolescents might be packaged for implementation in a typical educational setting is to translate a task matrix into a series of activities, drawing on a wide literature base to inform on how the activities should appear and be interacted with once in concrete form. In this instance, the activities were direct harvests from experimental literature and were short so that they could be flexibly fitted into form-time, in line with the context requirement to be separate from the main curriculum. This and the particular intervention design: self-management through a set of materials labelled using key visuals that was guided by visually uncluttered booklets allowed the implementation to run with some smoothness. However, metacognitive reflection was not promoted to the anticipated degree. This would require additional training input that could have been planned in.

5.3.3 Implications of the practical development work and implementation

This study was located within implementation research (Greenberg et al., 2005) as a part-efficacy, part-effectiveness trial. It is the effectiveness aspect that is primarily pertinent here. Could the intervention run in a real-world setting with the typical staffing and resources available? In the short-term but with some compromise on quality centring on facilitation, the answer would be yes. Within evaluation literature the study was located as an early stage evaluability
assessment (Weiss, 1998) that would require reasonably smooth operation in the intended environment to justify further investment of research effort. This criterion too appears to have been satisfied.

Implementation research provides ideas such as dosage, fidelity and adaptation that can be used to unpick these positive assertions (Durlak & Dupré, 2008).

**Dosage.** A particular dosage had not been identified as crucial. The intervention was scheduled to run for a convenient time period (half a term) with the total number of sessions in line with a middle course in comparison to nearest hit literature (Karbach & Kray, 2009; Röthlisberger et al., 2012). When it looked as though the dosage was going to become seriously compromised, the teaching assistant took the initiative to use an hour of PSHE time instead. Although this remediated the dosage, it compromised the fidelity of this particular package, see below.

**Adaptation.** Given that local adaptation is inevitable, an intervention programme should have built-in potential for modification (Greenberg, 2014). How this plays out is a subject for study (Durlak & Dupré, 2008; Lendrum & Humphrey, 2012). Arguably the pre-prototype produced in this research is a basis for intervention in any context. The process of local adaptation began when the particular prototype was designed to include short tasks that could fit flexibly into form-time and a de-cluttered booklet to guide students’ self-management. Despite the host school wanting to be open to change and new approaches (Durlak & Dupré, 2008), the reality was that the research needed to fit established organisational practice and a strong commitment to protect the learning time seen to contribute to performance measures, specifically external examination results (Durlak & Dupré, 2008). At this point, the local adaptation did not inevitably compromise fidelity, although it possibly reduced the likelihood of metacognitive reflection through discussion.

A second stage of local adaptation was how the implementation unfolded in response to class dynamics. This was at some discussion and therefore fidelity cost. The compromise was perhaps not inevitable and could have been

---

6 This researcher prefers the evaluation perspective as it seems to capture better the dynamic nature of design and that evaluation can improve a programme, not simply judge success in a particular context.
addressed through training, see below. However, using the intervention during PSHE time was an adaptation that almost certainly wouldn’t work. Set up for use in form-time, the short tasks were relatively repetitive and therefore tedious when used for an hour. This is not to say that PSHE couldn’t be used for EF intervention, but the pre-prototype to prototype translation (first stage local adaptation) would have been different and would probably have involved lengthier tasks.

Long term sustainability would seem to be a trickier issue in this context. The context demanded that the usual day-to-day commitments had to be met: form-time business and the teaching assistant’s other responsibilities. Equally, the students wanted to protect their lead-in time for the school day. This researcher believes that here long-term sustainability of an intervention of this kind would need further resource commitment (Durlak & Dupré, 2008) and specifically short sessions of protected and dedicated time.

Looking again at the training issue, in retrospect the teaching assistant’s initial stance regarding her training needs was consistent with previous research (Hanley & Darby, 2007; Torrance, Hanley & Darby, 2007). She and the form tutor were concerned with practical fidelity. The intervention needed to work in the classroom in the sense of being acceptable to students and being usable in an orderly way. Predictably after a number of sessions had established classroom routine, including supporting the boys, the teaching assistant could start to consider intervention principles and she had begun to promote reflection and discussion. She had started her journey from fidelity to ownership and appropriate adaptation (Hanley & Darby, 2007; Torrance, Hanley & Darby, 2007). However, she was not supported at this point; training around the discourse of EF was not offered. As Jaycox et al. (2006) suggest, the onus is on the researcher to maintain contact throughout an evaluation (in line with minimising participant workload) and therefore this researcher is at fault for not responding to the training need. Also, this researcher believes such ‘right moment’ training is a feature that should be designed into any implementation, since all facilitators would ideally make a similar journey from pragmatics to principle adapted to context.

In addition, this researcher would now argue that for an intervention that focuses on general cognitive skills, the targeted participants themselves should take a parallel journey. In this instance, they would get used to the materials and how to
self-manage and would then be provided with the language to discuss more effectively. The discourse of cognition is not the discourse of typical adolescents. To expect unsupported discussion of experiences using abstract materials that have distilled out the essence of EF and specifically Shift and further to expect students to make meaningful links from them to their life beyond is unrealistic\(^7\). By contrast, adolescents armed with the appropriate language would likely be more engaged with such an intervention, which in turn would promote Flow (Moneta & Csikszentmihalyi, 1996; Shernoff, et al., 2003) and creation of meaning through social mediation (Elbers & de Haan, 2005).

Looking towards the future, the specific prototype developed had sufficient fit with this demanding context (i.e. ran with sufficient smoothness) that with some additional time protection and facilitator and participant training built in at suitable points throughout, further trials within a secondary environment could be justified. Alternatively, the same prototype could be trialled in a slightly less demanding context, for example in a small group where discussion facilitation would be easier, as suggested by the teaching assistant. Here the above proposed mechanisms of developing discussion through introducing additional discourse could be studied in some detail. In the host school, one such potential context could be the ‘alternative provision’, where students are under less pressure to perform.

One benefit this researcher has derived from the implementation process is a timely reminder of the journey to be taken within training. This will shape day-to-day responses to requests for advice and training from schools. Better that training be delivered in response to a need and in several sessions over time, than as a one-off ‘good idea’.

### 5.4 RQ3: To what extent could such a Shift intervention package produce anticipated and/or useful benefits?

This section covers the implementation outcomes: any development in targeted skills that could be attributed to the intervention.

#### 5.4.1 Summary of results

For clarity these are separated under two headings: quantitative and qualitative.

\(^7\) In retrospect this researcher believes she may have offered more facilitation in the pilot work than she had realised.
5.4.1.1 The quantitative results

With the time series data abandoned, the standardised pre-/post- measure from the Inhibition subtest of the NEPSY-II constituted the quantitative data. Using the corrected retest scores (corrections based on published test/retest information), descriptive statistics for most measures indicated near effect improvements for the group as a whole. More specifically:

- the mean combined scaled scores increased for Naming (5.3 to 7.2), Inhibition (7.1 to 8.0) and Switch (6.5 to 7.8)
- the mean scaled score for Inhibition-Switch contrast increased (7.5 to 8.4) and
- the mean scaled score for Total Error increased (5.6 to 8.7).

However, the mean scaled score for Naming-Inhibition contrast remained unchanged, at 9.

Assuming the corrections removed artefactual (test-based) retest inflation from the group as a whole, it should be possible to accept the following significant improvements (Wilcoxon matched pairs tests):

- Naming, a large effect (Cohen’s d=0.90 or standardised response mean = 0.71), significant at the 99.5% level (one-tailed)
- Switch, a medium-sized effect (Cohen’s d=0.48 or standardised response mean = 0.60), significant at the 97.5% level (one-tailed) and
- Total Error, a large effect (Cohen’s d=1.14 or standardised response mean = 0.86), significant at the 99.5% level (one-tailed).8

The apparent improvement of Switch relative to Inhibition skills (Inhibition-Switch contrast) was not significant (just), and neither was the apparent improvement in Inhibition per se. The latter nevertheless may have reduced the Inhibition-Switch contrast change to its non-significant size.

Tentatively then it seems reasonable to assert from the numeric data that the student participants’ scores improved for the non-executive skill Naming and for the targeted EF skill Switch or Shift, with the latter perhaps receiving some contribution from non-significant improvements in Inhibition. A cautious exploration of patterns of raw score change suggested that it was primarily a

8 Power values were 0.93, 0.84 and 0.98 respectively.
reduction in the number of errors made that accounted for apparent Naming and Shift skill improvements. This is in line with the significant change in (and large effect size for) Total Error scaled scores. In turn then this suggests that improved monitoring skill, itself a metacognitive executive skill boosted performance on both the non-executive (Naming) and the EF (Switch) tasks.

Equally, the lack of mean change in the Naming-Inhibition contrast scaled score could suggest that improvements in non-executive Naming skills didn't create artefactual EF skill improvements. This is supported tentatively by the apparent lack of relationship between Naming and Shift score changes.

More cautiously still, it was noted that within the classroom there was a pocket of several students receiving no benefit from the intervention, in addition to single others spread about. A tentative link was made with non-engagement. Also the half of students with apparent initial lower Shift skill showed, on average, a greater increase in Shift combined scaled score.

5.4.1.2 The qualitative results
Perceived benefits reported by the facilitators were limited. The less involved form tutor felt there were none, whilst the teaching assistant could see some potential but was concerned that it had taken too long for students to reach difficult tasks and that time had precluded important discussions about the strategies that had allowed them to become “unstuck”. In suggesting that students had forgotten the aim of the intervention, both facilitators implicitly suggested that students needed a reinforced understanding of the rationale on which to hang and interpret their experiences. This ties in with some students finding it hard to describe why tasks were difficult and even what the intervention was for. One skill that students clearly noticed they had had to work on was error monitoring and this links with the quantitative results above.

5.4.2 Critique of outcomes
This critique addresses Research Question 3 with reference to the outcomes that appear to have been delivered through this intervention implementation.

---

9 An improvement on this non-executive skill is to be expected given that all training tasks required a naming response.
Before this it is important to consider the associated methods briefly as they provide crucial context against which apparent results are interpreted.

Regarding the quantitative methods, the lack of control group inherent in a single group pre-test post-test design creates a particular need to interpret carefully. However, the choice of measure (NEPSY-II Inhibition), the consistent timing of testing (morning) and the retest corrections applied\(^{10}\) should have promoted the identification of real increases in executive skill. Equally, although improvement from low initial scores might sometimes be interpreted as a regression to norm, in this instance the information about the particular cohort suggests that the baseline scores could have been a fair reflection of skill and that score increases could represent actual improvement. Nevertheless, the possibility of a Hawthorne Effect cannot be excluded, particularly as EF skill is vulnerable to change in affect (Pnevmatikos & Trikkaliotis, 2013; Willoughby et al., 2014; Yang & Yang, 2014).

Exploring this hypothesis further, generally within the school the study received little attention whilst it was ongoing; rather it almost needed to be inconspicuous. However, the teaching assistant who primarily ran the intervention is a popular member of staff (if this researcher's perception of reactions to her in the classroom can be taken as an indicator). Also, students appeared to enjoy having the researcher in the classroom and seemed happy to be retested.

Other qualitative data detract from the Hawthorne effect suggestion. Firstly, with students' previously discussed lack of understanding about the intervention, it seems unlikely that they would be able to consciously boost their retest scores except through concerted attempts to improve general concentration. Secondly, students did report the intervention doing something to them, whether that was messing with their head\(^{11}\) or getting them to improve their monitoring skills. Thirdly, by the end of the intervention, students reported being fed up and appeared to be honest about this with the researcher. They did not seem to feel

\(^{10}\) Observable qualitative carry-over effects underlined the importance of correction: during retest several students needed the practice items to remember to omit colour contingency on the first Inhibition section of the subtest.

\(^{11}\) Those who complained most were amongst those apparently relatively well-engaged. As indicated earlier, the researcher spent some time debriefing them and acknowledging their commitment to the research.
under any pressure to produce positive results and the researcher had made it clear this was not a requirement.

On balance, this researcher accepts her findings but acknowledges that they require confirmation with additional research involving control groups.

Regarding the qualitative methods, participant training in EF terms of discourse would now seem a prerequisite to asking about far effects during feedback interviews. As an alternative, far effect measures could be used such as academic performance, although it would be difficult to know when to take these, as far effect benefits might take time to accrue. Meanwhile, whether or not the intervention produced useful benefit must remain unknown.

Putting aside methodological issues and accepting the reported skill improvements as valid, they are in line with what would be predicted in terms of nearest effects within the Central Executive: an improvement in a measure of Shift skill and more effective use of monitoring skills (one aspect of metacognition).

Within the narrow range of measure taken, it would not be unreasonable perhaps to expect a significant improvement in Inhibition skill too. However, as Inhibition is the earlier skill to develop, by adolescence perhaps there is less potential to boost it. Although a standardised measure is designed to take this development into account, to interpret results at this level of detail is perhaps to ignore the contamination issues detailed in the literature and methodology chapters. The NEPSY-II interpretation manual itself mentions them (Korkman, Kirk & Kemp, 2007) in noting that within the whole Inhibition subtest, the Shift-plus-Inhibition–plus-Naming section is later and therefore scores can be inflated by earlier practise on Naming and Inhibition skills. However, tentative indications that Naming and Shift improvements were not related hopefully rule out Naming skill development accounting for all improvements in the Shift combined scaled score.

Looking at who benefitted most, data patterns indicating a link with engagement and lower initial skills must be regarded very tentatively. Nevertheless, seen in combination with qualitative data they make sense. Students more deeply engaged may have exposed themselves to a greater intervention effect. Students with initially less EF skill may also have experienced the intervention differently. They spent longer on tasks at a level that was difficult for them and/or were in effect in receipt of more facilitation either by the teaching assistant (for the boys) or
by their more able peers (for some girls). Equally those with greater initial EF skill perhaps did not receive the facilitation they needed and as the teaching assistant suggested they experienced reduced task difficulty.

Hence, looking to Research Question 3, the Shift intervention package appears to have produced some anticipated near effects, but there is no evidence of useful benefit. The possibility of the package being useful has not been excluded.

5.4.3 Implications

Despite its design flaws\(^\text{12}\), the study is methodologically in line with others (Röthlisberger et al., 2012) that appear within peer reviewed journals. Therefore it seems reasonable to suggest it constitutes a modest contribution to the necessary intervention evidence base of creating near effects (Gathercole et al., 2012). As such, it perhaps also contributes a little to proof of concept, or efficacy data (Greenberg et al., 2005).

In not demonstrating real-life benefit, the study is unfortunately also in line with numerous previous studies and reviews (e.g. Apter, 2012; Bryck & Fisher, 2011; Diamond, 2012; Hulme & Melby-Lervåg, 2012; Kray & Ferdinand, 2013). Therefore without further research and development work this author believes that the intervention created cannot yet be recommended as effective for use in schools. From the perspective of teaching staff and practising Educational Psychologists seeking effective evidence-based interventions, the study therefore doesn’t have immediate legacy. This point will be picked up again in the final section.

More positively, it arguably does constitute the kind of applied research needed to translate neuroscience into eventual education applications (e.g. Anderson & Reid, 2009; Goswami, 2006; Howard-Jones, 2008a; Mason, 2009). Whether or not the intervention becomes a finished product will not detract from the research’s contributions to knowledge and this author believes it is unrealistic to expect all prototypes to reach market.

Further, whether or not the particular intervention attracts future research depends partly on how it is perceived: brain training creating near effects or more than that.

\(^{12}\) Many are exactly those picked up by Apter (2012), for example lack of follow up measure, measures too similar to the training materials and lack of control group.
Despite precedence (Röthlisberger et al., 2012), the abstract appearance of the particular instance perhaps does not work in its favour. However, the evidence (quantitative and qualitative) hinting that error monitoring was improved suggests that despite the challenging implementation environment, metacognition was indeed usefully engaged and perhaps developed.

So rather than dismiss the specific intervention completely at this stage, perhaps effort should be directed to improve the facilitator and student journeys (Hanley & Darby, 2007), as described in the previous section. This could improve the quality of metacognitive discussion, a supposed critical intervention mechanism and hence also the intervention fidelity (Durlak & Dupré, 2008; Lendrum & Humphrey, 2012). Any wider benefits could then plausibly be captured through interview data as participants might then know how to recognise and describe them.

Further research should also look at whether improved implementation sustains the tentative result that those with weaker initial EF skills benefit most, this being in line with previous conclusions (Diamond, 2012).

Lastly, in this section, this researcher would welcome peer comment on the attempt to remove some EF retest issues (Miyake & Friedman, 2012; Salthouse, 2014) through score correction.

### 5.5 A review of the study overall and final conclusions

As an early evaluation, or evaluability assessment (Weiss, 1998), this study aimed to create an intervention prototype and assess its worth for further study. This assessment was to be in three stages that are now also useful for gaining an overview of what the study may have achieved.

**i) logical examination of the intervention’s underlying theory.** A theoretical exploration was supported by discussion with EF experts. This allowed the development of several outputs, all of which contain aspects of novelty:

- a theoretical rationale for EF intervention including (and perhaps especially) for adolescents,
- a modified model of EF, combining models from Baddeley (2012) and Miyake et al. (2000) and
- a modified description of EF development based on performance on Shift tasks.

These were used to propose mechanisms of intervention benefit: a) Shift skills themselves could be stretched and developed and b) EF as a whole could be
challenged by loading the requirement for all three core components. Identifying these mechanisms then allowed the creation of a task matrix that embodied them. This was the pre-prototype that formed the basis for the particular intervention then developed. It could equally support other instances. Inevitably other theoretical underpinnings were possible, but that does not invalidate these and they seem to be more comprehensive than others this researcher has found.

ii) assessment of whether the intervention can operate as intended and with some smoothness within the proposed environment. By choosing to have a range of participants, the environment imposed was form-time in a Year 8 classroom. This was beneficial in providing a description of differing patterns of engagement that in turn allowed a suggestion for how metacognitive reflection could be better supported: training designed to support both facilitators and students in a journey from pragmatic usage to more meaningful engagement in part through the acquisition of an EF discourse. With this improvement, the intervention might operate with greater effectiveness as all proposed benefit mechanisms could be utilised. This is a link the teaching assistant had made, “the communication thing is really important but we were constrained by time and the curriculum.” Looking to what went well, the intervention supported students’ orderly exposure to tasks of increasing Shift and overall EF difficulty in short and messy form-time sessions. The reporting of a notionally complete implementation for an intervention of this kind within a secondary setting is an additional novel contribution to the research area.

If a small group implementation had been used instead, facilitation would likely have promoted better metacognitive discussion for all participants and there perhaps would have been stronger proof of concept. However, avoiding facilitation difficulties at this stage would likely have precluded the identification of essential implementation features that needed improvement. Equally, using a group could have introduced ethical issues around who should be selected and why.

iii) an evaluation of outcomes to identify positive results. On limited measures (parts of the NEPSY-II Inhibition subtest) that were corrected (in a novel way) with the intention of reporting conservative result estimates, the significant improvements found would appear to contribute to the evidence that EF
intervention, here with a focus on Shift, can produce near effect benefits including for adolescents.

The challenge is to identify how and where real-life benefits (far effects) might accrue. This researcher is proposing that students empowered by knowledge of EF discourse might themselves unlock some suggestions as to how intervention benefits can be generalised (in a way they simply couldn’t within this research). If this could be achieved, there would perhaps be a greater chance of secondary schools providing dedicated (or indeed curriculum-integrated) spaces for all students to explore EF, as the time would be seen as contributing to the current results agenda.

Overall, the prototype could be said to have passed its evaluability assessment. The fact that some quantifiable effectiveness appears to have been demonstrated within such a loosely controlled implementation seems to indicate a degree of robustness. Equally, this study has produced several whiffs of positive result (whiff being used in the broader sense of having moved one or more research areas forward in some way), as indicated by the novel contributions noted above. All of these require a wider airing to gather peer reaction.

Having reviewed what the study as a whole may have achieved, it is appropriate to look at the overall main implications for future research and practice and also to critically assess the overall approach to intervention development including some of the associated techniques. These aspects will be tackled in this order.

**Suggestions for future research** have already been indicated as they arose during the individual discussions for each research question. Here is the place to draw them together. At a theoretical level, there is work to be done to reconcile the differing accounts of EF, so that suggested intervention mechanisms become more integrated into a coherent picture. Specifically it seems important to provide a description that relates the three components drawn on in this research with higher level processes and particularly metacognition. This description should be mindful of the current knowledge of how each of these cognitive processes mature, as well as the neuroscientific knowledge that details brain substrate development.

At a more practical level, this study suggests a number of avenues for future exploration. Firstly, this author has suggested that introducing adolescents to the
discourse of EF might provide a mechanism for allowing the generalisation of intervention near benefits. This strategy would fit with their naturally developing metacognitive skills. It could be studied with the intervention in its current form, but perhaps recruiting a small group of adolescent participants and ensuring that discourse training was given at the appropriate times, as learned from the lessons of this study.

Secondly, the intervention itself could be further developed to sustain novelty value for longer and perhaps to increase its appeal to adolescent users. At a superficial level, a greater number of tasks could be generated with the same underlying structure, but with easily named items that seem more age appropriate. More ambitiously, the tasks could be embedded in age appropriate context. Again, the underlying structure would be the same, but it would be less obvious. A approximate analogy would be the well-known Wason and Johnson-Laird (1972) four card reasoning task where logic is laid bare or immersed in context. However for EF tasks, it would be important to monitor the non-EF skills/knowledge being introduced. Whilst the tasks might feel more like real-life scenarios, they might also require inappropriate non-EF skills that could cause the intervention to be diluted.

A third avenue could involve using a known intervention with some evidence base, such as learning martial arts and then exploring how this relates to the theoretical underpinnings derived in this study.

Fourthly and perhaps most simply, this study requires at least some implementation replications to support or refute its findings.

Turning next to suggestions for future practice, some changes to this researcher’s personal working have already been indicated. For example, her additional awareness of EF and its implications for engagement in the classroom has allowed the reframing of several ‘naughty’ and/or dis-engaged students. In turn in some instances this has allowed supportive measures to be put in place, often starting with co-regulation of attention and emotion. Equally, wherever a WISC-IV gives lower Working Memory scores, this researcher is now primed to look out for wider EF difficulty, since she now sees the skill set as intimately intertwined. Also, when Working Memory training has been requested, this author now asks if the remit can be widened to at least mention EF more broadly. In
addition, it has been useful to draw on the intervention materials when giving training on EF, to provide short activities that give a flavour of the underlying skills. These changes to practice seem appropriate to suggest to all Educational Psychologists.

Drawing more specifically from the implementation findings, this researcher has suggested to one school that a possible purchase of CogMed could be usefully complemented with group discussion. Short sessions where users of CogMed discuss and reflect on what the intervention asks them to do, might optimise its effect through enlistign metacognition more effectively.

Another possibility for more interested schools might be to use the current Shift intervention in a regular lesson slot, but one that is not high risk in terms of affecting results. This draws on the findings that students are able to self-manage and use the intervention in sessions of just a few minutes and that it may produce at least near effect benefits. This might fit as a starter for science or personal, social, health and economic (PSHE) education lessons. However, it would be important to ensure the availability of this researcher or another Educational Psychologist to provide the appropriate training.

A further implication for EP future practice might be to encourage primary schools to consider actively developing their pupils’ EF skills during perhaps Years 5 and 6, as part of the preparation for transition to high school. Personal experience suggests that the primary school environment more naturally supports poorer EF skills and that some students then find they struggle with the additional EF draw exerted by typical secondary education settings.

Turning now to the overall approach to intervention development, it has already been suggested that the prototype arrived at was only one of many possible instances. In itself this is not necessarily a problem since several versions could have had equal merit. However in retrospect a tangible method/benchmark to make such a judgement of value might have added a degree of robustness.

More specifically, it would likely have been useful to include a more systematic user needs analysis early on, to provide a reference point for later developments. Unpicking this suggestion, firstly it would have made it clearer who the intervention was for and why: a narrower student population whose members could usefully remediate poorer skills or students at various levels of EF skill who could all
benefit from a performance boost. In turn, this might have prompted more signposting within the intervention to ensure participants engaged themselves at an appropriate level of difficulty.

Secondly, having user needs defined more explicitly up front may have prompted this researcher to outline more clearly the utility and relevance of EF to classroom learning. Shift could have been better described in real-life terms within the intervention as a skill that allows people to respond flexibly to the unexpected. This could have been drawn upon within discussions in school, so reminding participants more regularly of the purpose of the research. Equally perhaps this researcher would have had to be more explicit about which parts of the pre-prototype matrix best capture ‘responding to the unexpected’.

Thirdly, creating a user needs analysis would have provided a systematic way to collate needs identified through the various sources: several areas of literature, the pilot work and discussion with experts. In retrospect, some needs identified earlier on in the pilot work became lost, such as the requirements for sustained novelty and for students to be able to use their own creativity. These loses are acknowledged (see 5.2.2). Whilst Figure 4.5 contains plenty of evidence-based practical suggestions, they are not a systematic response to need and they are not well integrated with EF features.

Fourthly, it would have been better to have a user needs analysis amongst the materials presented to the stakeholder group, rather than the acutely abstract matrix of task difficulty. This would have provided stakeholders with a systematic means to evaluate the materials they were shown, beyond their correctly instinctive “will this work in my classroom?” Perhaps some potentially useful features such as the cartoon discussion prompts would then have survived into the prototype used.

These various points do not necessarily suggest that the intervention developed lacked quality. Indeed, this author believes that the planned features would have fulfilled many of the requirements set by a user needs analysis. Rather, there isn’t the means to show this systematically. Equally, it must be remembered that there were several user categories to consider when designing this intervention for real-world use. These emerged clearly from the stakeholder group: the students, the
facilitators and the school. Balancing each need perspective would arguably require inevitable compromises in places.

In the discussion so far on approach to intervention development, it has been assumed that a manualised programme was to be produced for which staff and students would receive training. From the school perspective this could be similar to buying an almost ready off-the-shelf product. Different approaches to effective intervention development have been tried. For example, Hedges (2010) used consultative training sessions so that all the teachers in a primary school could find out about classroom strategies that support EF and could consider how they might use them within their own classes. Arguably this approach leads to the facilitators (teachers) driving their own journey to appropriate adaptation and for generalisation of facilitation to potentially be relatively embedded throughout the school curriculum. This therefore might seem a preferable development approach. However, this researcher was not sure that the method would transfer to a secondary education setting and did not consider using it. In hindsight, careful selection of adult participants to for example cover all lessons for a particular student cohort might be one possible introductory approach.

Looking briefly at the main qualitative data analysis method used, this researcher was somewhat wary of producing a thesis populated with Braun and Clarke (2006) Thematic Analyses. On reflection, this method has served its purpose perhaps because it is flexible and free of epistemological position. Equally, it was used as per Braun and Clarke’s (2006) criteria of quality: it was used comprehensively in terms of full and checked transcription and all coded excerpts being collated under the relevant themes. In addition, there were some inter-rater reliability measures in place and explicit decisions were made about usage: inductive versus deductive. The analyses were more than “once-over-lightly” (Braun & Clarke, 2006, pg.98).

Finally a note on the epistemological position adopted: Critical Realism. In the journey through this study, it has been necessary to move between positions:
- a relatively Positivist interpretation of neurocognitive research;
- a Critical Realist understanding that the study products (theoretical and practical) reflect a single account of the truth;
- a Critical Realist evaluation, triangulation and interpretation of numeric findings through use of mixed methods and specifically through reference to multiple
participant perspectives;
- some Pragmatism perhaps, where circumstance necessitated use of next best methods;
- a Social Constructivist interpretation that adolescents who learn to speak about EF will then recognise EF skills and benefit more from intervention.

In describing this movement between epistemologies, this thesis provides evidence that Educational Psychologists are indeed well-placed to conduct applied neuroscience research. This is not to understate the challenge, especially in a field where burgeoning literature makes it difficult to maintain a current knowledge.

To conclude, EF intervention research in adolescence has perhaps received some useful and novel contributions from this study:

i) An attempt to create an EF intervention that is firmly linked with theory.

ii) An explicit theoretical rationale for EF intervention and one suggestion of theoretical underpinnings that includes a modified model of working memory, suggested mechanisms of benefit and proposals for how to create systematic changes in task difficulty.

iii) A particular worked example of a prototype intervention with evidence-based suggestions for how it could be usefully further developed, particularly around the training that should be provided at the right moments to support appropriate discourse and understanding in all participants.

iv) Some evidence that the particular intervention was able to deliver a quantifiable whiff of near effects within an applied setting, with all the expected lack of control that this brings. This quantitative evidence is a conservative estimate as it was subjected to a novel way to correct retest data.
References


Boddy, C. (2005). A rose by any other name may smell as sweet but “group discussion” is not another name for “focus group” nor should it be. *Qualitative Market Research, 8*(3), 248-255.


Department for Education and Department of Health (DfE, DoH) (2015). *Special educational needs and disability code of practice: 0 to 25 years*. London: HMSO.


Eslinger, P.J., Flaherty-Craig, C.V. & Chakara, F.M. (2013). Rehabilitation and management of executive function disorders. In M.P. Barnes & D.C. Good (Eds.),


Gopher, D., Greenshpan, Y., & Armony, L. (1996). Switching attention between tasks: Exploration of the components of executive control and their development...


doi:10.1348/026151008X357886


Health and Care Professions Council (2012). *Standards of conduct, performance and ethics*. London: Health and Care Professions Council


rs10503253 affects general cognitive ability and executive function in healthy males. *Schizophrenia Research, 154*(1-3), 42–47. doi:10.1016/j.schres.2014.02.017


Lara, T., Madrid, J. A., & Correa, Á. (2014). The vigilance decrement in executive function is attenuated when individual chronotypes perform at their optimal time of day. *PLoS ONE, 9*(2), e88820. doi:10.1371/journal.pone.0088820


Skelton, R.P. (2012). *Increasing every child’s capacity to learn: the development and evaluation of a whole class Working Memory training programme.* (Doctoral thesis, University of Manchester, Manchester, UK.)


207


Appendix 1: Glossary of terms

**Acquired brain injury (ABI):** brain damage caused by events after birth. Technically it does not include damage caused by perinatal events.

**ADHD:** a group of behavioural symptoms that include inattentiveness, hyperactivity and impulsiveness. Common symptoms of ADHD include: a short attention span or being easily distracted; restlessness, constant fidgeting or overactivity; being impulsive.

**Anterior cingulate (AC):** the anterior cingulate cortex (ACC) is the frontal part of the cingulate cortex that resembles a "collar" surrounding the frontal part of the corpus callosum. The anterior cingulate circuit is involved when increased arousal and attention are required, especially when activities are effortful and need heightened monitoring of responses and errors or conflicting information has to be dealt with. It may not actually carry out high-level co-ordination, but instead alert the dorsolateral circuit.

**Attention:** the behavioral and cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources.

**Attentional shift (or shift of attention):** occurs when attention is focused in to increase the efficiency of processing of a stimulus and it includes inhibition to decrease attentional resources to unwanted or irrelevant inputs. Shifting of attention is needed to allocate attentional resources to more efficiently process information from a stimulus.

**Autism:** a lifelong developmental disability that affects how a person communicates with, and relates to, other people. It also affects how they make sense of the world around them.

**Comic strip conversations:** a technique to help people with autism to develop greater social understanding. They provide visual representations of the different levels of communication that take place in a conversation, using symbols, stick figure drawings and colour. By seeing the different elements of a conversation presented visually, some of the more abstract aspects of social communication (such as recognising the feelings and intentions of others) are made more 'concrete' and are therefore easier to understand.

**Critical period:** a phase in the life span during which an organism has heightened sensitivity to environmental stimuli that are compulsory for the development of a particular skill. If the organism does not receive the appropriate stimulus during this "critical period", it may be difficult, ultimately less successful, or even impossible, to develop some functions later in life.

**Critical Realism:** a theory that suggests there are unobservable events which cause the observable ones; as such, the social world can be understood only if people understand the structures that generate such unobservable events. Critical Realism theory does not have predictive power, and the theory is used for its
explanatory benefits. Critical theory requires a deep understanding of any social situation, going beyond the observable and investigating the mechanisms behind any event.

**Diffusion Tensor Imaging (DTI):** a magnetic resonance imaging technique that detects how water travels (diffuses) along the white matter tracts in the brain in order to produce neural tract images. (Also known as diffusion MRI.)

**Dimensional Change Card Sorting task (DCCS):** a measure of cognitive flexibility. Two target pictures are presented that vary along two dimensions (e.g. shape and color). In one version, participants are asked to match a series of bivalent test pictures (e.g. yellow balls and blue trucks) to the target pictures, first according to one dimension (e.g. color) and then, after a number of trials, according to the other dimension (e.g. shape).

**Distributed practice:** a learning strategy where practice is broken up into short sessions over a period of time. (Also known as spaced repetition or spaced practice).

**Dorsolateral prefrontal cortex (DLPFC or DL-PFC):** an area in the prefrontal cortex of the brain of humans and primates. It is one of the most recently evolved parts of the human brain and it undergoes an extremely prolonged period of maturation that lasts until adulthood. It mediates attention, focus, the ability to shift focus, Working Memory, planning and the generation of fluent response.

**Educational Psychologist (EP):** professional concerned with helping children or young people who are experiencing problems within an educational setting with the aim of enhancing their learning.

**Educational Psychology Service (EPS):** a group of Educational Psychologists typically (though not necessarily) working for a local authority to the benefit of children and young people in the local area.

**ERP, or event-related potential:** the measured brain response that is the direct result of a specific event. It is measured using electroencephalography (EEG) i.e. the recording of electrical activity along the scalp.

**Evaluability assessment (of an programme/intervention):** a qualitative investigation employed before a programme is evaluated. Evaluability assessments go further than merely providing information of whether a programme can be evaluated or not. They are used to describe the objectives, logic and activities of the programme with an aim to investigate its credibility, feasibility, sustainability and acceptability. They address the likelihood of the programme achieving its anticipated outcomes, the required changes needed for optimum management, whether an evaluation can improve the programme’s performance and to identify stakeholder interests in the evaluation and how the findings will be used.

**Executive Function (EF):** a set of general purpose control processes that regulate one's thoughts and behaviours; they are the command and control
functions of the pre-frontal cortex. EF is broadly implicated in the control of both cognitive processing and affective self-regulation.

**Fidelity (of programme implementation):** refers to the degree to which an intervention or programme is delivered as intended. Only by understanding and measuring whether an intervention has been implemented with fidelity can researchers and practitioners gain a better understanding of how and why an intervention works, and the extent to which outcomes can be improved.

**fMRI or functional magnetic resonance imaging:** a functional neuroimaging procedure using MRI technology that measures brain activity by detecting associated changes in blood flow.

**Gray matter volume (GMV):** this changes during the course of normal brain development and can be used as an indication of development over time. It is measured using brain MRI scans (magnetic resonance imaging scans).

**Hawthorne Effect:** the alteration of behaviour by the participants of a study due to their awareness of being observed.

**Heritability:** the portion of variability across individuals within a particular sample attributable to genetic effects at a particular point in time.

**Implementation research:** the scientific study of methods to promote the uptake of research findings. It explores the challenges that are faced when generalising research findings 'in the real world', for example in school based education.

**Inhibition:** the ability to suppress a dominant or automatic or pre-potent response.

**Instructional Hierarchy:** a model of learning with four stages: acquisition, fluency, generalization, and adaptation. First described by Haring, Lovitt, Eaton and Hansen in 1978. Forms the theoretical backdrop to Precision Teaching, used for the acquisition of basic academic knowledge. (Also known as the Learning Hierarchy.)

**Interleaved Learning/practice:** involves working on multiple skills in parallel. (Also known as varied practice, variable practice, and mixed practice.)

**IQ, or intelligence quotient:** a score derived from one of several standardised tests designed to assess human intelligence.

**Local Authority (LA):** an administrative body in local government, i.e. the group of people responsible for the government of a particular area, town, or city in the UK.

**Learning hierarchy:** a model of learning with four stages: acquisition, fluency, generalization, and adaptation. First described by Haring, Lovitt, Eaton and Hansen in 1978. Forms the theoretical backdrop to Precision Teaching, used for the acquisition of basic academic knowledge. (Also known as the Instructional Hierarchy.)

**Long-term depression (LTD):** an activity-dependent reduction in the efficacy of neuronal synapses lasting hours or longer following a long patterned stimulus.
LTD occurs in many areas of the central nervous system with varying mechanisms depending upon brain region and stage of development.

**Long-term potentiation (LTP):** a persistent strengthening of synapses based on recent patterns of activity. These are patterns of synaptic activity that produce a long-lasting increase in signal transmission between two neurons. It is one of several phenomena underlying synaptic plasticity, the ability of chemical synapses to change their strength. As memories are thought to be encoded by modification of synaptic strength, LTP is widely considered one of the major cellular mechanisms that underlies learning and memory. (The opposite of LTP is long-term depression, see above.)

**Massed practice:** consists of fewer, longer training/learning sessions.

**Metacognition:** “knowing about knowing”. It includes knowledge about when and how to use particular strategies for learning or for problem solving.

**Mixing cost:** the additional time taken for a mixed trial block compared with a single trial-type block in typical Shift task paradigms.

**Office for Standards in Education, Children’s Services and Skills (Ofsted):** a non-ministerial department of the UK government. The services Ofsted inspects or regulates include: local services, childminding, child day care, children’s centres, children’s social care, CAFCASS, state schools, independent schools and teacher training providers, colleges, and learning and skills providers in England.

**Orbitofrontal cortex (OFC):** a prefrontal cortex region in the frontal lobes in the brain which is involved in the cognitive processing of decision-making. Anatomically the OFC is synonymous with the ventromedial prefrontal cortex, but it has distinct neural connections and distinct functions.

**PATHS Curriculum (PATHS):** The PATHS (Providing Alternative THinking Strategies)® Curriculum is a program for educators and counsellors that is designed to facilitate the development of self-control, emotional awareness, and interpersonal problem-solving skills. Hence it also aims to reduce aggression and behaviour problems and enhance the educational process in the classroom. Designed for use with preschool through to elementary school children.

**Principal Educational Psychologist (PEP):** the typical title of the head of an EPS.

**Plasticity (of the brain):** refers to changes in neural pathways and synapses which are due to changes in behavior, environment and neural processes, as well as changes resulting from bodily injury. (Also known as neuroplasticity.) Neuroplasticity has replaced the formerly-held position that the brain is a physiologically static organ, and explores how - and in which ways - the brain changes throughout life.

**Positivism:** the philosophy of science that information derived from logical and mathematical treatments and reports of sensory experience is the exclusive source of all authoritative knowledge, and that there is valid knowledge (truth) only
in this derived knowledge. Verified data received from the senses are known as empirical evidence.

Pre-frontal cortex (PFC): the thick outer layer (cerebral cortex) of the prefrontal lobe (the front portion of the frontal lobe). It has been implicated in planning complex cognitive behavior, personality expression, decision making, and moderating social behavior, in short Executive Function.

Prepotent response: a response for which immediate reinforcement (positive or negative) is available or has been previously associated, making it the most likely/available response unless consciously overridden (by Executive Function).

Personal, social, health and economic (PSHE) education (PSHE): defined by the schools inspectorate (Ofsted) as a planned programme to help children and young people develop fully as individuals and as members of families and social and economic communities. Its goal is to equip young people with the knowledge, understanding, attitudes and practical skills to live healthily, safely, productively and responsibly.

Schema: a pre-existing cognitive framework or concept that helps organise and interpret information. Schemas can be useful because they allow efficient interpretation of the vast amount of information available in the environment.

Selective attention: the capacity for or process of reacting to certain stimuli selectively when several occur simultaneously.

Special educational needs (SEN): these can affect a child’s ability to learn and can include: behaviour or ability to socialise, e.g. not being able to make friends; reading and writing, e.g. they have dyslexia; ability to understand things; concentration levels, e.g. they have Attention Deficit Hyperactivity Disorder; physical needs or impairments.

Special educational needs and disability (SEND): SEN as above plus disability: a physical or mental impairment which has a long-term (year or more) and substantial adverse effect on the ability to carry out normal day-to-day activities.

Special Educational Needs Coordinator (SENCo): a SENCo is responsible for the day-to-day operation of the school's SEN policy.

Shift Cost: the difference in accuracy and performance between a task repeat (A-A) and a task switch/Shift (A-B).

Shift (or set-Shift): the ability to shift between mental states, operations, or tasks.

Simon Effect: reactions are usually faster and more accurate when the stimulus occurs in the same relative location as the response, even if the stimulus location is irrelevant to the task.

Social Constructionism: a theory of knowledge in sociology and communication theory that examines the development of jointly constructed understandings of the world. It assumes that understanding, significance, and meaning are developed not separately within the individual, but in coordination with other human beings.
The elements most important to the theory are (a) the assumption that human beings rationalise their experience by creating a model of the social world and how it functions and, (b) that language is the most essential system through which humans construct reality. (Also known as the social construction of reality.)

**Stroop**: a demonstration of interference in the reaction time of a task. When the name of a colour (e.g., "blue," "green," or "red") is printed in a colour not denoted by the name (e.g., the word "red" printed in blue ink instead of red ink), naming the colour of the word takes longer and is more prone to errors than when the colour of the ink matches the name of the colour.

**Sustained attention** defined as the ability to maintain concentrated attention over prolonged periods of time. (Also known as sustained concentration or vigilance.)

**Switch**: used by some authors to distinguish between a change in mental set/response required, ie Shift, and a change in physical response correspondingly generated, ie Switch. For other authors Shift and Switch are interchangeable. Yet others use Switch to refer to task change and Shift the mental set change needed to deal with it.

**Task set**: defined as an effective intention to perform a task, accomplished by configuring one's mental state (e.g. attention) to be in accordance with the specific operations demanded by the task. Tasks that have been used to define these task sets include: categorization of numbers, letters, or symbols; identification of colors or words (e.g. using Stroop effect stimuli); location judgments; semantic and episodic memory tasks; and arithmetic problems.

**Teaching assistant (TA)**: supports teachers and helps children with their educational and social development, both in and out of the classroom.

**Tools of the Mind (TOOLS)**: an early childhood program that builds foundations for school success by promoting intentional and self-regulated learning in preschool- and kindergarten-aged children.

**Trailmaking**: a neuropsychological test of visual attention and task switching. It consists of two parts in which the subject is instructed to connect a set of 25 dots as fast as possible while still maintaining accuracy. It can provide information about visual search speed, scanning, speed of processing, mental flexibility, as well as executive functioning.

**Updating**: a term more-or-less synonymous with Working Memory, the ability to maintain and manipulate information over brief periods of time.

**Wisconsin Card Sorting Task (WCST)**: a trademarked version of the Dimensional Change Card Sorting task. There are numerous variations on this task: Miyake et al. (2000) presented stimuli on a computer one at a time to be sorted into 1 of 4 piles, according to a particular dimension, for example, shape or colour. After 8 successful trials, the sorting dimension changed.

**Working Memory**: the ability to maintain and manipulate information over brief periods of time.
Appendix 2: Appendices for Chapter 2

Appendix 2.1 Information regarding the literature search

This appendix starts on the next page.
Table A2.1: Key research papers

<table>
<thead>
<tr>
<th>Literature review section</th>
<th>Authors</th>
<th>Title</th>
<th>Type of study, outcomes and issues</th>
<th>Contribution to this research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Miyake et al. (2000)</td>
<td>The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: a latent variable analysis.</td>
<td>Analysis of 137 adults’ performance on EF tasks led to identification of three core components through confirmatory factor analysis. Choice of tasks may have affected the final model, but this choice was based on a review of neuroscience literature and a conscious focus on basic skills rather than higher skills e.g. ‘planning’. Outcome generalisability could be affected by participant choice: college students.</td>
<td>Provides model of EF.</td>
</tr>
<tr>
<td></td>
<td>Miyake and Friedman (2012)</td>
<td>The nature and organization of individual differences in Executive Functions: four general conclusions.</td>
<td>Review of their work on EF, to propose modified Unity and Diversity model and that EF shows stability over time and genetic contribution. It is also related to important life phenomena. As a review, it does not give detail about how conclusions are reached, but instead refers to other papers.</td>
<td>Description of EF issues such as measurement difficulties and heritability.</td>
</tr>
<tr>
<td></td>
<td>Willoughby et al. (2014)</td>
<td>Executive Functions: formative versus reflective measurement.</td>
<td>Statistical and theoretical re-examination of key papers identifying EF components. By own admission, distinguishing statistical techniques are embryonic. This author cannot understand their vanishing tetrads by reading the paper.</td>
<td>Critiques the statistical basis for the Miyake models.</td>
</tr>
<tr>
<td>Literature review section</td>
<td>Authors</td>
<td>Title</td>
<td>Type of study, outcomes and issues</td>
<td>Contribution to this research</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------</td>
<td>-------</td>
<td>-----------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>EF associations: Shift</td>
<td>Yeniad et al. (2013)</td>
<td>Shifting ability predicts math and reading performance in children: a meta-analytical study.</td>
<td>Meta-analysis of 20 studies contributing over 1000 children. Shift was related to maths and reading skills; effect sizes seem small to moderate (smaller for reading) but were reported as substantial, although less than for IQ. IQ does not seem to have been controlled for effectively.</td>
<td>Indicated importance of Shift skill per se.</td>
</tr>
<tr>
<td>EF intervention</td>
<td>Karbach and Kray (2009)</td>
<td>How useful is executive control training? Age differences in near and far transfer of task-switching training.</td>
<td>Randomised controlled trial laboratory computer-based training of Shift in children (mean age 9) and adults (young - mean age 22, older - mean age 69), 56 in each group. Mainly large effect sizes for near (within EF) effects. Greater training effect for children and older adults. (75% participants involved in Shift training.)</td>
<td>Evidence of proof of concept for near measures.</td>
</tr>
<tr>
<td></td>
<td>Röthlisberger et al. (2012)</td>
<td>Improving executive functions in 5- and 6-year-olds: evaluation of a small group intervention in prekindergarten and kindergarten children.</td>
<td>Evaluation in educational setting: quantitative quasi-experimental, between-subject design with mainly randomised assignment to condition. Intervention used tasks harvested from EF assessments as basis for training. Measures were computer-based versions of EF tasks similar to those used in training. Mainly large effect sizes. (135 participants split into two groups including control.)</td>
<td>Precedence for: - using EF assessment tasks in intervention - intervention in educational setting.</td>
</tr>
<tr>
<td></td>
<td>Zinke et al. (2012)</td>
<td>Plasticity of executive control through task switching training in adolescents.</td>
<td>Intervention evaluation using computer-based training of Shift. Design was three-factorial with two between subjects factors, Shift training and exercise, and one within subject factor, time of measurement (pre/post). Cannot evaluate intervention as dosage too low. Also, effect sizes not reported. (20 participants per group.)</td>
<td>Precedence for: - Shift training with adolescents.</td>
</tr>
<tr>
<td>Literature review section</td>
<td>Authors</td>
<td>Title</td>
<td>Type of study, outcomes and issues</td>
<td>Contribution to this research</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------</td>
<td>-------</td>
<td>-----------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Shift task exploration – others are shown in Appendix 2.8.</td>
<td>Davidson et al. (2006)</td>
<td>Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching.</td>
<td>Research exploring differences in performance on EF tasks which have required skills analysed. There are task ‘gaps’ in terms of covering the complete skill range indicated; this is not obvious at first reading as the paper is so complex. Effect sizes not calculated. (325 participants, about 30 per age group.)</td>
<td>Results give experimental support to idea that EF is of limited capacity and so performance on one core skills affects performance on others.</td>
</tr>
<tr>
<td></td>
<td>Zelazo et al. (2003)</td>
<td>The development of Executive Function in early childhood.</td>
<td>Series of experiments that show young children’s Shift skills, through systematically varying task dimensions.</td>
<td>Indicates presence of basic component skills in children as young as three.</td>
</tr>
<tr>
<td>Literature review section</td>
<td>Authors</td>
<td>Title</td>
<td>Type of study, outcomes and issues</td>
<td>Contribution to this research</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------</td>
<td>-------</td>
<td>-----------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Implementation and evaluation research</td>
<td>Durlak and Dupré (2008)</td>
<td>Implementation matters: a review of research on the influence of implementation on program outcomes and the factors affecting implementation.</td>
<td>Review of five meta-analyses plus additional papers; total number of papers covered was 542. Used findings to distil out important implementation features such as dosage and fidelity and to create ecological framework.</td>
<td>Outline of implementation issues to consider.</td>
</tr>
<tr>
<td></td>
<td>Greenberg et al. (2005)</td>
<td>The study of implementation in school-based prevention research: theory, research and practice.</td>
<td>Review done for US department for health and human services.</td>
<td>Suggests a series of stages from concept to wide dissemination. Indicates when implementation issues need to be considered.</td>
</tr>
</tbody>
</table>
Results from additional database search to ensure neuropsychiatry literature covered

None of the literature indicated in the three tables below is cited in the references since it is not used.

**Web of Science search:** ‘Executive Function’ in title and ‘intervention’ as keyword and restriction to psychiatry and neurosciences research areas produced 218 results. These were all briefly viewed and 19 papers were retained for further exploration, see below. Two were finally integrated into the main literature review to counter-balance other more positive reviews of intervention.

**TRIP search:** ‘Executive Function’ in title and ‘intervention’ as keyword and produced 87 results. These were all briefly viewed and three were retained that had not already been picked up. None were finally integrated into the literature review.

**Table A2.2:** Results from searching Web of Science on 22/12/14.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Brief outline of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biederman et al. (2007)</td>
<td>Suggest early recognition and intervention for EF deficit in children with ADHD, as these deficits otherwise show stability over time and into adulthood.</td>
</tr>
<tr>
<td>Bugas et al. (2007)</td>
<td>Older adults showed improved EF 3 months after a piano instruction intervention had finished.</td>
</tr>
<tr>
<td>Calhoun (2006)</td>
<td>An overview of EF, including possible connections between EF deficit and social communication difficulties in children with ASD. Suggests interventions to help with social interaction that take into account EF issues: Plan-Execute-Repair (a way to encourage delayed responding) and Thinking Maps and self-talk strategies.</td>
</tr>
<tr>
<td>Chan, Sze &amp; Han (2014)</td>
<td>An intranasal herbal medicine given to children with ASD for 6 months appeared to improve EF skills.</td>
</tr>
<tr>
<td>Crone (2009)</td>
<td>A brief review of studies on adolescent EF concluding that EF improves, but there is also vulnerability to social context. Author cites Working Memory training as evidence that EF intervention can be successful.</td>
</tr>
<tr>
<td>Diamond (2014)</td>
<td>A brief critique that indicates playing football (as a form of coordinative exercise) does not, in fact, boost EF in children.</td>
</tr>
<tr>
<td>Eslinger et al. (2013)</td>
<td>A review of approaches to ‘rehabilitation of EF impairments’, behavioural and pharmacological. Concludes that specific behavioural domains can be identified for treatment (such as attention and Working Memory) but that the evidence base is slim especially regarding long-term real-world outcomes.</td>
</tr>
<tr>
<td>Hartman et al. (2010)</td>
<td>For children with learning difficulties, motor and EF appear to be linked such that joint intervention would be appropriate.</td>
</tr>
<tr>
<td>Authors</td>
<td>Brief outline of content</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Krasny-Pacini, Chevignard &amp; Evans (2013)</td>
<td>A review of studies using Goal Management Training to help with EF after brain injury. It was effective only in combination with daily life problem solving therapies.</td>
</tr>
<tr>
<td>Marlowe (2000)</td>
<td>Suggests that in theory teaching metacognitive strategies through a cognitive-behavioural approach to children with EF difficulties would be a suitable intervention, as it would support verbal mediation of self-regulation, a skill often lacking.</td>
</tr>
<tr>
<td>Nikulina &amp; Spatz Widom (2013)</td>
<td>People subjected to childhood maltreatment were followed into adulthood and found to have poorer EF in their 40s. Neglect on its own had similar predictive power, whereas physical and sexual abuse did not.</td>
</tr>
<tr>
<td>Rabin et al. (2011)</td>
<td>Multiple EF measures predict procrastination regarding college work in you adult students.</td>
</tr>
<tr>
<td>Rapport et al. (2013)</td>
<td>A meta-analysis of 25 studies of cognitive training with children with ADHD. Memory training helped memory, but other EF training seemed ineffective. There was no generalisation to academic functioning.</td>
</tr>
<tr>
<td>Romer et al. (2011)</td>
<td>Suggest typical sensation seeking in adolescence is not due to EF deficit and is different from youngsters who act without thinking (poorer EF).</td>
</tr>
<tr>
<td>Tate et al. (2014)</td>
<td>An international group of researchers and clinicians working with adults with TBI reviewed EF intervention evidence and recommended programs that involve metacognitive strategy. The authors suggest that the plethora of programs available is confusing and that the evidence base is currently weak.</td>
</tr>
<tr>
<td>Wolfe et al. (2014)</td>
<td>Links the EF deficit and social skills difficulties commonly found in survivors of childhood brain tumours.</td>
</tr>
</tbody>
</table>
### Table A2.3: Results from searching TRIP on 22/12/14.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Brief outline of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilman et al (2014)</td>
<td>9 months on an after-school physical activity programme improved 7-9 year olds fitness levels and aspects of their EF skills.</td>
</tr>
<tr>
<td>Kennedy et al (2008)</td>
<td>A meta-analysis of 5 RCT studies exploring the use of metacognitive strategy instruction with young to middle-aged adults with TBI showed this to be a useful approach. Data doesn't allow generalisation to children. Authors say evidence for other approaches is not sufficient to make other clinical recommendations yet.</td>
</tr>
<tr>
<td>Mitchell et al (2013)</td>
<td>Mindfulness appeared to help with EF (self and clinician ratings) in adults with ADHD. However it had no effect on EF measures.</td>
</tr>
</tbody>
</table>

### Results from additional database search to ensure thesis literature covered

**ETHOS search:** 'Executive Function*' in title produced 14 results. These were all briefly viewed and 4 papers were retained for further exploration, see below. None of the below was used. Two others were identified through university contacts (Hedges, 2010; Skelton 2012) and have been used to a limited extent; they were not taken as key papers as they did not meet the inclusion criteria of having appeared in a peer reviewed journal.

### Table A2.4: Results from searching ETHOS on 22/12/14.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Brief outline of content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cragg, L. (2008)</td>
<td>Studying 5 to 11 year olds, essentially confirmed the fractionation of EF in childhood into the three components (Miyake et al., 2000) and that Inhibition matures first. Working Memory and Shift were still developing at 11 years.</td>
</tr>
<tr>
<td>Mcardle, P. (2013)</td>
<td>Attempted indirect support of EF development in two children in foster care, through conjoint consultation. The results were mixed/limited.</td>
</tr>
</tbody>
</table>
Appendix 2.2: A broader description of EF definitions and conceptions

Executive function (EF) as a whole can be defined as “a set of general purpose control processes that regulate one’s thoughts and behaviours” (Miyake & Friedman, 2012, pg. 8) or as the “command and control’ functions of the prefrontal cortex” (Powell & Voeller, 2004, pg. 785), or indeed as the “superordinate, managerial capacity for directing more modular activities, including language, memory, motor skills and perception in the service of setting, managing and attaining goals” (Levin & Hanten, 2005, pg. 79). It is broadly implicated in the control of both cognitive processing and affective self-regulation¹ (Best, Miller, & Jones, 2009; Friese, Binder, Luechinger, & Boesiger, 2013; Martel, Roberts, & Gremillion, 2013) and it underlies “the ability to adjust behaviour rapidly and flexibly to the varying demands of the environment” (Huizinga & van der Molen, 2007, pg. 193), and similarly to “behave flexibly, rather than being slaves to our environment and always behaving in a stereotyped manner when particular events occur” (Gilbert & Burgess, 2008, “Role of executive processes, ” para. 2).

The term EF has arisen from observations that adults with damage to the prefrontal cortex might have intact sensory processing, speech, intelligence and/or movement, but would tend to have difficulty with planning, organising, controlling/sustaining and adapting their thoughts and behaviours (Best et al., 2009; Gilbert & Burgess, 2008; Shallice and Burgess, 1991).

Since these observations were first made, there have been attempts to detail EF more exactly by describing its constituent parts (Best et al., 2009), in terms of the cognitive processes, and the supporting brain anatomy and physiology. As a psychologist, this researcher’s work firmly focusses on suggested cognitive components. Nevertheless it is informed by and arguably should not run counter to neuroscience findings. Hence the brief visit to anatomy and physiology in Appendix 2.3. and an engagement with the debate regarding the application of neuroscience to education in Section 2.4.1.1. Similarly, the majority of accounts drawn on below do not use neuroscience as a rationale, but tend to invoke its support for their validity.

The first two accounts operationalise EF as processes needed to plan and direct activities.

- **Dawson and Guare (2010)** describe two high-level components:
  - **thinking skills to select and achieve goals or to develop problem solutions**: planning, organisation, time management, Working Memory and metacognition.
  - **skills to guide behaviour along the path to a goal**: response inhibition, emotional control, sustained attention, task initiation, flexibility and goal directed persistence.

- **Lezak, Howieson, & Loring (2004)** describe four components:

---

¹ Since affect can modify performance on traditional cognitive tasks (Pnevmatikos & Trikkaliotis, 2013; Yang & Yang, 2014), this researcher has chosen to adopt these broad EF definitions, in line with some authors (Brocki & Bohlin, 2004; Levin & Hanten, 2005), whilst recognising others prefer to describe cognitive processing (cool EF) and affective self-regulation (hot EF) separately (Hongwanishkul, Happaney, Lee & Zelazo, 2005; Prencipe et al., 2011; Schoemaker et al., 2013).
- **volition**, the capacity for intentional behaviour (as opposed to reflex reactions)
- **planning**, the identification of steps and elements needed to achieve the goal
- **purposive action**, the translation of a plan into sequences of coordinated complex behaviour, and
- **self-regulation**, the maintenance of productivity and the ability to be flexible and shift.

The components themselves do not appear to have a direct evidence base, but they do conveniently relate to task achievement and they do draw on neurocognitive functions, such as sustained attention and Working Memory. (See glossary for brief definitions of these and other terms.)

A second kind of EF conception looks at EF hierarchically and the associated models draw more heavily and directly on neuroscience. For example, looking at deliberate new learning, Chein & Schneider (2012) describe a model made up of three hierarchical brain systems. The first of these constitutes the new knowledge/skills learned, whilst the second and third control the learning process, i.e. they constitute EF. Looking at the second in more detail, the Cognitive Control Network has the function of guiding attention, inhibiting irrelevant information and using complex routines in novel ways. As such it has well developed connectivity with many brain areas. As learning progresses and new routines become automatic, it becomes less involved. The third system is the Metacognitive and ultimate control system. It is involved in the most complex and abstract tasks and when new learning initially commences. It controls the Cognitive Control System and although also primarily located in prefrontal cortex its connectivity is relatively local.

Similarly, Kopp (2012) and Marcovitch & Zelazo (2009) conceptualise EF in terms hierarchies of decision making units. Kopp (2012) supports his ideas with the finding that increasingly abstract decisions are associated with more rostral areas of the pre-frontal cortex. Presumably these decisions are the domain of Chein and Schneider’s (2012) Metacognitive System.

A third way of looking at EF is simply to list parallel EF skills. Anderson, Northam, Hendy & Wrennall (2002) list:
- attentional control: directed attention and sustained attention
- cognitive flexibility: Working Memory, attentional shift, self-monitoring and conceptual transfer
- goal setting: initiating, planning, problem-solving and strategic behaviour.

Similarly Levin & Hanten (2005) list:
- maintenance of a problem-solving set for future goals
- organisation of behaviour over time as in planning
- flexibility in problem solving
- self-monitoring and self-regulation
- conforming to rules of social behaviour
- skilful use of strategies
- using reward and punishment to facilitate learning.
Fourthly and finally, some authors have attempted to uncover underlying fundamental processes and components. Miyake and her colleagues have used statistical techniques (confirmatory factor analysis) to identify core components of EF as used to carry out experimental EF tasks such as the Wisconsin Card Sort Task\(^2\) (Miyake et al., 2000). As well as identifying some common processing, they have found that three distinguishable components each contribute separately to performance on general EF tasks:

- Inhibition, the ability to suppress a dominant or automatic or prepotent response
- Updating of Working Memory, that is the ability to maintain and manipulate information over brief periods of time and
- Shifting, the ability to shift between mental states, operations, or tasks (Miyake et al., 2000).

Looking instead at processes, Buss and Spencer (2014) present their dynamic neural field (DNF) model which can simulate a number of findings in EF development research, again in the context of a card sort task. The model is made up of:

- simulated neural populations that attend to particular stimuli dimensions, and
- two supervisory systems (one excitatory, the other inhibitory) that are activated by the neural populations according to their excitation thresholds.

They suggest that their model is able to demonstrate how functions very much in line with the Miyake et al. (2000) components ‘naturally’ emerge from the neural dynamics.

Miyake and her colleagues (Miyake & Friedman, 2012) have since revisited the three component model and proposed a modified version where common EF is conceived to be the ability to maintain goals and related information so as to effectively direct lower-level processing, see Figure A2.1. Inhibition is discarded because it correlates almost perfectly with common EF.

Their idea of EF comprising both Unity (common process) and Diversity (specific functions) seems to acknowledge the broad regulation and monitoring function of EF as well as to recognise core underlying skills.

\begin{figure}
\centering
\begin{tabular}{|c|c|c|}
\hline
& Unity & Diversity \\
\hline
Updating ability & = & Common EF \\
Shifting ability & = & + \\
Inhibition ability & = & + \\
\hline
\end{tabular}
\caption{Miyake and Friedman's (2012) unity and diversity model}
\end{figure}

\(^2\) See glossary.
It seems to this researcher that the different ways of conceptualising EF all have some validity, each emphasizing a particular aspect, whether that be overall EF control or contributory skills and processes. The rationale for adopting one model over another in this research has been largely pragmatic and has resulted in a choice of the three core component model set out in Miyake and her colleagues’ earlier paper (Miyake et al., 2000). The reasons for this are fourfold:

- it provides the basis for discourse in much of the relevant research (Best et al., 2009; Best & Miller, 2010; Levin & Hanten, 2005; Willoughby et al., 2014).
- it is an accepted model of adult functioning against which all child and adolescent behaviour can be compared (Garon, Bryson, & Smith, 2008). As will be seen later, EF appears to become increasingly differentiated as children develop and with that development the best-fit model changes. Indeed, Miyake and Friedman’s (2012) newer model could arguably be an artefact of their participants’ age, 16 to 17 year olds as opposed to the young adults in their earlier work (Miyake et al., 2000).
- the Inhibition component appears to have explanatory power in social skills interventions (Riggs, Greenberg, Kusché, & Pentz, 2006).
- there are tasks available that are suggested/commonly used to capture the three core component skills (Miyake et al., 2000).

Exactly how EF should be conceptualised has yet to be resolved (Bogg & Roberts, 2013; Hall & Fong, 2013; Miyake & Friedman, 2012); Koziol (2014) likens the issue to “trying to nail Jell-o to a wall” (Koziol, 2014, pg.161).

---

3 There are exceptions, for example Burnett, Scratch & Anderson (2013) use Anderson et al.’s (2002) EF conceptualisation.

4 The two models will be further critiqued theoretically later on, in reference to recent pertinent work (Herd et al., 2014; Willoughby et al., 2014).
Appendix 2.3: EF links with brain anatomy and physiology

EF is primarily associated with pre-frontal cortex (Powell & Voeller, 2004). This part of the brain receives pre-processed sensory, emotional and autonomic information and has access to memory (Powell and Voeller, 2004) and as such is well placed to house and control interactions between higher and lower level processes (Gilbert & Burgess, 1990).

More specifically, the neural substrates for EF comprise:

- a main location in prefrontal cortex, with dorsolateral and ventrolateral prefrontal cortex being the key areas supporting Working Memory, Inhibition and Shift skills (Levin & Hanten, 2005), and

- frontally guided, distributed neural networks involving prefrontal sub-regions, posterior cortex, including virtually all major sensory and motor areas, and subcortical structures including basal ganglia and ventral striatum (Gilbert & Burgess, 2008; Levin & Hanten, 2005). Evidence that implicates extended circuitry includes data from brain injured patients: Miyake et al. (2000) report that some patients with frontal lobe damage maintain adequate EF, whilst lesions outside this area can affect it.

A number of authors attempt to locate EF components more precisely (e.g. Gilbert & Burgess, 2008) but this is tricky (Gilbert & Burgess, 2008) and a number of factors contribute to the complexity and confusion:

- the pattern of activation seen on a scan depends as much on the lower processing involved as the EF component(s) used (Levin & Hanten, 2005)
- there is considerable overlap in the brain areas and EF processing used for tasks intended to provoke different specific component skills (Levin & Hanten, 2005; Morton, 2014)
- there are different scan types (event-related potentials (ERPs), grey and white matter volume (GMV and WMV) and functional magnetic resonance imaging (fMRI) and different results patterns (main activity versus “critical” activity areas) to integrate.

The resulting impression this researcher has is that clear cut component – brain mappings are not yet easy or perhaps possible to create, although a degree of agreement seems to exist regarding regional connectivity differences within prefrontal cortex:

- Orbitofrontal cortex is particularly implicated in response inhibition (Huizinga & van der Molen, 2007; Kopp, 2012; Logue & Gould, 2014; Powell & Voeller, 2004)
- Medial prefrontal cortex, including anterior cingulate cortex, is particularly implicated in effortful and flexible /shifting attention (Huizinga & van der Molen, 2007; Logue & Gould, 2014; Powell & Voeller, 2004) and its dysfunction leads to apathy (Kopp, 2012)
- Dorsolateral prefrontal cortex is particularly implicated in Working Memory: manipulating information and making plans (Gilbert & Burgess, 2008;)

\[\text{A table of exemplary studies can be found below.}\]

\[\text{See glossary and Goswami (2004).}\]
Some further detail can be found in Figure A2.2, below.

Gilbert and Burgess (2008) additionally mention rostral prefrontal cortex, which appears to co-ordinate the most complex planning, reflection and social perception activities and hence, this author suggests, may house metacognition and/or highest level common EF.

Looking beyond the anatomy of the brain, EF biology could be described in more physiological i.e. neurochemical (Logue & Gould, 2014) or electrical terms (Benikos, Johnstone, & Roondenrys, 2013). Although this researcher has had to engage with the associated literature to, for example, better understand EF development, a detailed description seems an unnecessary digression here. It suffices to suggest that some parallel demarcations are indicated (Logue & Gould, 2014).

**Medial prefrontal cortex.** The anterior cingulate circuit seems to be particularly involved when increased arousal and attention are required, especially when activities are effortful and need heightened monitoring of responses and errors or conflicting information has to be dealt with (Powell and Voeller, 2004). Authors variously suggest that the anterior cingulate circuit:
- does not actually carry out high-level co-ordination, but instead alerts the dorsolateral circuit (Gilbert and Burgess, 2008).
- is a predictor and evaluator of likely outcomes of planned actions, before the actions are performed, so providing a chance to think before acting (Brown, 2013).
- is implicated in social cognition, the recognition of emotion and the ability to take others’ perspectives (Taylor, Barker, Heavey, & McHale, 2013).

**Dorsolateral prefrontal cortex.** The dorsolateral circuit mediates attention, focus, the ability to shift focus, Working Memory, planning and the generation of fluent response (Ezekiel et al., 2013; Powell and Voeller, 2004); the modality of information being processed seems to affect the specific area of dorsolateral prefrontal cortex involved.

**Orbitofrontal cortex.** Connectivity is made up of a lateral and a medial pathway; together they modulate social behaviour, taking into account emotional and autonomic information and memory. It has less direct effect on purely cognitive functions, but acts through the mediating effects of inhibition, and hence shifting and maintaining focus (Powell and Voeller, 2004).

*Figure A2.2: Diagram of prefrontal cortex and related structures – taken from Powell and Voeller (2004)*
Table A2.5: Examples of studies attempting to locate EF components

<table>
<thead>
<tr>
<th>Component</th>
<th>Area</th>
<th>Age</th>
<th>Data type</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task conflict resolution - Stroop</td>
<td>ACC (has connections to many brain areas including PFC).</td>
<td>Adults</td>
<td>Neuroimaging during Stroop</td>
<td>Evidence cited in Kalanthroff, Goldfarb, Usher, &amp; Henik (2013)</td>
</tr>
<tr>
<td>Task conflict resolution</td>
<td>ACC (part of medial PFC) that alerts DLPFC</td>
<td>Adults</td>
<td>ERPs</td>
<td>Review by Gilbert and Burgess (2008)</td>
</tr>
<tr>
<td>Switch (without conflict)</td>
<td>Lateral PFC and posterior parietal cortex. In adults only there are changes in activity in left posterior parietal cortex and right middle frontal gyrus.</td>
<td>Children and adults</td>
<td>fMRI activity</td>
<td>Review by Best &amp; Miller (2010)</td>
</tr>
<tr>
<td>Shift</td>
<td>Activity increases during adolescence in inferior frontal, parietal and ACC and reduces in DLPFC. Also changes in medial PFC by mid-adolescence for processing unexpected events and changes in left dorsal PFC by late adolescence for hypothesis testing.</td>
<td>Children and adults</td>
<td>Neuroimaging</td>
<td>Review by Best &amp; Miller (2010)</td>
</tr>
<tr>
<td>Shift</td>
<td>Activation increase to adult levels in inferior frontal, parietal, and anterior cingulate regions.</td>
<td>Children and adults</td>
<td>ERPs</td>
<td>Review by Best, Miller, &amp; Jones (2009)</td>
</tr>
<tr>
<td>Switch</td>
<td>DLPFC, VLPFC, inferior frontal junction, premotor cortex, pre-SMA, ACC, insula, cerebellum</td>
<td>Adults</td>
<td>Neuroimaging</td>
<td>Evidence cited in Davidson, Amso, Anderson, &amp; Diamond (2006)</td>
</tr>
<tr>
<td>Switch (+inhibition of previous response)</td>
<td>Medial PFC</td>
<td>Adults</td>
<td>Neuroimaging</td>
<td>Evidence cited in Huizinga &amp; Molen (2007)</td>
</tr>
</tbody>
</table>

Abbreviations used in the table:
- DLPFC: dorsolateral pre-frontal cortex
- VLPFC: ventrolateral pre-frontal cortex
- DMPFC: dorsomedial pre-frontal cortex
- PPC: posterior parietal cortex
- ACC: anterior cingulate cortex
<table>
<thead>
<tr>
<th>Component</th>
<th>Area</th>
<th>Age</th>
<th>Data type</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working memory – executive control</td>
<td>More PFC activity for more complicated tasks</td>
<td>Children aged 8 months to 8 years</td>
<td>ERPs</td>
<td>Review by Best and Miller (2010)</td>
</tr>
<tr>
<td>Working memory</td>
<td>Capacity of working memory is related to activity in intraparietal cortex and DLPFC</td>
<td>Children and adults</td>
<td>ERPs</td>
<td>Review by Klingberg (2010)</td>
</tr>
<tr>
<td>Working memory</td>
<td>Widely distributed circuitry including: VLPFC, DLPFC, medial frontal regions, the striatum, PPC, etc</td>
<td>Children and adults</td>
<td>fMRI</td>
<td>Review by Luna, Padmanabhan, &amp; O’Hearn (2010)</td>
</tr>
<tr>
<td>“Common” limited processing capacity</td>
<td>Lateral frontal/prefrontal cortex</td>
<td>Adults</td>
<td>ERP and fMRI studies</td>
<td>Review by Marois &amp; Ivanoff (2005)</td>
</tr>
<tr>
<td>Working memory central executive</td>
<td>Better on DSB if less GMV in frontal and pre-frontal regions including left anterior insular cortex.</td>
<td>10 year olds</td>
<td>Grey Matter Volume compared with performance on Digit Span Backwards</td>
<td>Rossi et al. (2013)</td>
</tr>
<tr>
<td>Short-term information storage ie phonological loop-type tasks</td>
<td>VLPFC</td>
<td>Adults</td>
<td>ERPs</td>
<td>Review by Gilbert and Burgess (2008)</td>
</tr>
<tr>
<td>Component</td>
<td>Area</td>
<td>Age</td>
<td>Data type</td>
<td>Data source</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------</td>
<td>--------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Inhibition</td>
<td>Increasingly activity is localised within PFC</td>
<td>Children aged 8 months to 8 years</td>
<td>EEG activity</td>
<td>Review by Best and Miller (2010)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>NOGO N2 as above. Decreases in amplitude with age through childhood – reflecting increased efficiency and/or reduction in conflict created.</td>
<td>Children aged 7 to 17</td>
<td>ERP during GO/NOGO inhibition tasks</td>
<td>Review by Best, Miller, &amp; Jones (2009)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>PFC – activity becomes more focussed throughout childhood.</td>
<td>Children and adults</td>
<td>ERPs during inhibition tasks</td>
<td>Review by Best, Miller, &amp; Jones (2009)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>NOGO N2 evoked in frontal area by stimulus requiring inhibition. (Also NOGO P3 that contrasts with GO P3; is more anterior.)</td>
<td>Adults</td>
<td>ERP during GO/NOGO inhibition training</td>
<td>Evidence cited in Benikos, Johnstone, &amp; Roodenrys (2013)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>Several regions in DLPFC</td>
<td>Adults</td>
<td>ERP</td>
<td>Review by Gilbert and Burgess (2008)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>Right inferior frontal gyrus</td>
<td>Adults</td>
<td>Performance by lesion patients</td>
<td>Review by Hu et al. (2013)</td>
</tr>
<tr>
<td>Executive control of attention</td>
<td>Frontal lobes, lateral PFC and ACC.</td>
<td>Adults</td>
<td>Performance by lesion patients</td>
<td>Review by Hu et al. (2013)</td>
</tr>
<tr>
<td>Inhibition of response</td>
<td>Orbito-frontal cortex</td>
<td>Adults</td>
<td>Neuroimaging</td>
<td>Evidence cited in Huizinga &amp; Molen (2007)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>DMPFC – but strong communication with DLPFC in self-regulation (when ventral medial and dorsal medial perhaps have monitoring and evaluation role). The ACC is also involved in a monitoring capacity – it triggers PFC activity.</td>
<td>Adults</td>
<td>Mixed neuroimaging techniques</td>
<td>Review by Hunt et al. (2013)</td>
</tr>
<tr>
<td>Response inhibition</td>
<td>VLPFC and widely distributed circuitry</td>
<td>Children and adults</td>
<td>fMRI</td>
<td>Luna et al. (2010)</td>
</tr>
<tr>
<td>Inhibition</td>
<td>DMPFC activity increases between adolescence (18-19 years) and adulthood (23-25 years), whether cognitive or emotional Stroop. For all ages, lateral frontoparietal and medial parietal are involved in cognitive Stroop. For all ages, left precentral and postcentral gyrus are involved in emotional Stroop.</td>
<td>Older adolescents and adults</td>
<td>fMRI during Stroop tasks</td>
<td>Veroude, Jolles, Croiset, &amp; Krabbendam (2013)</td>
</tr>
</tbody>
</table>
Appendix 2.4: Associations between EF and outcome measures

Table A2.6: Associations between EF and outcome measures

<table>
<thead>
<tr>
<th>a) Associations within childhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>- EF is positively associated with social competence in 3-5 year olds (Alduncin, Huffman, Feldman, &amp; Loe, 2014).</td>
</tr>
<tr>
<td>- adolescents who report being excessively sleepy tend also to have poorer EF skills (Anderson, Storfer-Isser, Taylor, Rosen, &amp; Redline, 2009).</td>
</tr>
<tr>
<td>- there is a positive relationship between EF and reading and maths achievement up until the age of 17 (the top end of a large 1400 strong sample) (Best, Miller &amp; Naglieri, 2011).</td>
</tr>
<tr>
<td>- EF appears to be related to social and emotional self-regulation and academic achievement (Best et al., 2009) – a review.</td>
</tr>
<tr>
<td>- adolescents’ EF skills correlate with their adaptive behaviour scores (Clark, Prior, &amp; Kinsella, 2002).</td>
</tr>
<tr>
<td>- parental ratings of emotional regulation and cognitive flexibility for 5 to 9 year olds are related to results on a screener for at risk of developing conduct disorder (Duncombe, Havighurst, Holland, &amp; Frankling, 2013).</td>
</tr>
<tr>
<td>- better EF is associated with more established (right) handedness and more efficient use of space in construction tasks in 5-6 and 9-10 year olds (Gonzalez et al., 2014).</td>
</tr>
<tr>
<td>- measures of EF in 3, 4 and 5 year olds are related to their counter-factual beliefs (Guajardo, Parker, &amp; Turley-Ames, 2009).</td>
</tr>
<tr>
<td>- young people (aged 7 to 17) who seek help with Obsessive Compulsive Disorder (OCD) have poorer EF although there isn’t a relationship with severity (Lewin et al., 2014).</td>
</tr>
<tr>
<td>- EF in kindergarten is related to academic achievement, especially in maths in Year 1 and mediates achievement – background relationship (Nesbitt, Baker-Ward, &amp; Willoughby, 2013).</td>
</tr>
<tr>
<td>- there is a strong and significant correlation between EF and academic performance in 7 to 8 year olds (Neuenschwander, Cimeli, Röthlisberger, &amp; Roebers, 2013).</td>
</tr>
<tr>
<td>- EF (as measured by the BRIEF self—report) in 9 year olds has a modest but significant negative correlation with substance abuse (tobacco and/or alcohol) 6 months later, but a positive association with engagement in physical activity outside school (Pentz &amp; Riggs, 2013).</td>
</tr>
<tr>
<td>- EF as a whole in pre-schoolers has a moderate correlation with their difficult behaviours and measures for each component each are associated with some effect (Schoemaker, Mulder, Deković, &amp; Matthys, 2013).</td>
</tr>
<tr>
<td>- EF difficulties are typical for adolescents (aged 13 to 14 years) with arithmetic difficulties (Van Daal, Leij, &amp; Ader, 2012).</td>
</tr>
<tr>
<td>- neuropsychological variables, particularly EF, can account for 40% of English and 30% of maths test variances in achievement tests given to children aged 9 to 12 years in schools serving low income areas (Waber, Gerber, Turcios, Wagner &amp; Forbes, 2006).</td>
</tr>
<tr>
<td>- EF at age 5 is related to early literacy and maths skills (Willoughby, Blair, Wirth &amp; Greenberg, 2012).</td>
</tr>
</tbody>
</table>

There is some disconfirming evidence:
- Riggs, Blair and Greenberg (2004) did not find concurrent relationships between Inhibition skills and internalising/externalising behaviour, although Inhibition did predict these behaviours over a 2 year period. The authors suggest there may be a developmental lag between acquisition of EF capacity and its use in everyday behaviours. Their explanation is less disconfirming, but more fitting with the next section (c). |
- results showing EF associations with outcome variables could be spurious (Willoughby, Kupersmidt, & Voegler-lee, 2012). Firstly the authors replicated the typical finding that pre-schoolers’ EF performance correlates with academic achievement. Then they used an alternative analytic method, fixed effects analysis, and associations become non-significant. The authors concluded that stronger methodologies must confirm causal inference before relevant public policy is adopted. This seems a reasonable conclusion, but some recent studies below
would appear to do this.

- EF accounts for much less school readiness if vocabulary skills are controlled for (Fitzpatrick, McKinnon, Blair, & Willoughby, 2014) – but perhaps EF skills allow better vocabulary acquisition – they predict the development of receptive vocabulary skills in pre-schoolers (Weiland & Barata, 2014).

<table>
<thead>
<tr>
<th>b) Predictions within childhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>- EF skills in pre-schoolers provide them with an immediate head start in maths and reading that is maintained throughout their first three years of school (Bull, Espy and Wiebe, 2008).</td>
</tr>
<tr>
<td>- EF at 3 years predicts performance in early maths assessments up to 5 years old (Clark, Sheffield, Wiebe, &amp; Espy, 2013).</td>
</tr>
<tr>
<td>- Poor EF skills at 8½ predict school functioning in literacy, maths and social sciences (Diamantopoulou &amp; Rydell, 2007).</td>
</tr>
<tr>
<td>- EF measures taken at 3 years mediate relations between language skills at 2 years and problem behaviours at 4 years old and the direct associations between EF and problem behaviour are strong at this age (Hughes &amp; Ensor, 2008).</td>
</tr>
<tr>
<td>- the size of improvements in EF between the ages of 4 and 6 predicts teachers’ ratings of behavioural issues and children’s perceptions of their own academic competence at 6 years (Hughes &amp; Ensor, 2011).</td>
</tr>
<tr>
<td>- frontal brain activity (and maternal positive affect) in babies of 10 months predicts their EF at age 4 – 5 years (Kraybill &amp; Bell, 2013).</td>
</tr>
<tr>
<td>- EF in 6 year olds predicts school readiness 6 months later for maths, English and especially science (Nayfield, Fuccillo, &amp; Greenfield, 2013).</td>
</tr>
<tr>
<td>- EF at the age of 7 predicts performance on standardised achievement tests of literacy and numeracy at age 8, even once fluid intelligence is controlled for (Neuenschwander, Röthlisberger, Cimeli, &amp; Roebers, 2012).</td>
</tr>
<tr>
<td>- EF at 4½ to 6 years predicts reasoning skills at 10 to 15 years (Richland &amp; Burchinal, 2013)</td>
</tr>
<tr>
<td>- EF levels in children aged between 6 and 8 years does not show associations with behaviour problems at that time, but does predict problem behaviour over the next 2 years (Riggs, Blair, &amp; Greenberg, 2004).</td>
</tr>
<tr>
<td>- performance on neuropsychological tests of EF is a significant predictor of real-world risk-taking in adolescents and emerging adults (Pharo, Sim, Graham, Gross &amp; Hayne, 2011).</td>
</tr>
<tr>
<td>- EF measures taken in primary school predicts how well children then fare socially and academically in middle school (less external support) (Jacobson, Williford &amp; Pianta, 2010). Teachers in primary schools seemed more aware of the difficulties for children with lower EF skills. After transfer to middle school, it was the parents who rated the issues more strongly. (Similar informal observations prompted this author to try to introduce an intervention into the secondary environment.)</td>
</tr>
</tbody>
</table>

**There is disconfirming evidence:** EF (Working Memory and Inhibition) in 5 and 6 year olds only indirectly affects reading/writing skills a year later, via behavioural control (Monette, Bigras, & Guay, 2011). The authors initially found Early Years EF skills to be associated with maths and literacy skills at age seven. Once they had controlled for preacademic abilities, affective variables and family variables, only Working Memory contributed and just to maths. In addition, Working Memory and Inhibition indirectly affected literacy skills via anger-aggression. The evidence would not seem to be disconfirming, so much as suggesting mechanisms.
### c) Predictions from childhood to adulthood
- girls’ EF measured between 6 and 12 years of age predicts academic outcomes (especially maths), school suspensions/expulsions and employment status 10 years later (Miller, Nevado-Montenegro & Hinshaw, 2012) in a sample that contained 50% of participants with a diagnosis of ADHD.

### d) Associations within adulthood:
- EF measures in older adults account for significant amounts of the variance in functional ability (Ahmed & Miller, 2013).
- self-report measures of emotional regulation difficulties are negatively associated with Inhibition skills in men and with Inhibition and cognitive flexibility skills in women (Bardeen, Stevens, Murdock, & Lovejoy, 2013).
- violent offenders and perpetrators of domestic violence have poorer EF, especially verbal Working Memory and adaptive decision-making (De Brito, Viding, Kumari, Blackwood, & Hodgins, 2013; Romero-Martínez, Lila, Sariñana-González, González-Bono, & Moya-Albiol, 2013; Zou et al., 2013).
- obese individuals show greater difficulty with decision-making, planning and problem-solving, although the research is often not good quality (Fitzpatrick, Gilbert, & Serpell, 2013). This review conclusion is supported by evidence that across adulthood, people with stronger EF (especially Inhibition) consume fatty food less frequently (Hall & Fong, 2013) and that EF is related to healthy eating behaviours: inhibitory control is associated with avoiding saturated fats whilst Working Memory is associated with initiating fruit and vegetable consumption (Allom & Mullan, 2014).
- older adults who have better EF find it easier to implement health enhancing behaviour changes (specifically taking additional exercise) (Hall, Zehr, Paulitzki, & Rhodes, 2014).
- poorer EF in stroke victims is associated with poorer physical functioning (Hayes, Donnellan, & Stokes, 2013).
- drinking and smoking is associated with greater Working Memory and planning deficit than either behaviour on their own (Heffernan, Ramzan, & O’Neill, 2014).
- EF appears to be more impaired in depressed people who attempt suicide than in depressed people who don’t (Keilp et al., 2013).
- EF has been suggested as part of the ‘risk’ mechanism in schizophrenia: healthy adults with certain gene types known to be implicated in schizophrenia had poorer EF (Koiliari et al., 2014).
- EF appears to mediate the effects of aging on memory in healthy adults (Kim, Kwon, & Shin, 2013).
- cognitive deficits including EF mediate the psychosocial impairment (notably the inability to go to work) found in those with major depressive disorder (McIntyre et al., 2013).
- Post-traumatic Stress Disorder (PTSD) is associated with poorer EF, particularly in people with more of the “numbing” symptoms (Olff, Polak, Witteveen, & Denys, 2014).
- cognitive flexibility and Inhibition correlate with sleep hygiene in university students (Todd & Mullan, 2013).
Appendix 2.5: Factors that influence the development of EF skills

Table A2.7: Factors that influence the development of EF skills.

<table>
<thead>
<tr>
<th>Biological conditions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- children born pre-term and/or with a low birth weight. EF and social competence are lower in 3-5 year olds who were born pre-term (Alduncin et al., 2014). The picture is not straightforward. EF difficulties seem to persist into adolescence (Burnett et al., 2013 - a review) versus specific findings that deficits seen in 8/9 year olds largely disappear by 10 to 13 years (Ritter, Nelle, Perrig, Steinlin, &amp; Everts, 2013). It seems that effects depend on how pre-term and how light children are born: EF measures are overall around 0.36 to 0.57 standard deviations lower but they correlate with birth weight and gestational age (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, &amp; Oosterlaan, 2009) and by age 6 they are less severe than previously although more pronounced for children with lower birth weight and gestational age (Baron, Weiss, Litman, Ahronovich, &amp; Baker, 2014). The effects on EF at 4 years old for children born very pre-term seem to be mediated at least in part by white matter abnormalities seen around the time of birth (Woodward, Clark, Pritchard, Anderson, &amp; Inder, 2011).</td>
</tr>
<tr>
<td>- children with a short corpus callosum at 6 weeks have poorer EF (measured by parental BRIEF ratings) at 4 years (Ghassabian et al., 2013)</td>
</tr>
<tr>
<td>- children who have (treated) iron-deficiency anaemia in infancy show poorer inhibitory control at age 10 (Algarin et al., 2013).</td>
</tr>
<tr>
<td>- children with acquired brain injury. For example those who have seizures after surgery in infancy have poorer EF skills at age 4 despite other skills being intact (Gaynor et al., 2013) and children aged 8 to 18 years who have had brain tumours have inconsistent EF skills 18 months after treatment has finished and some associated difficulties with social skills. Similarly, adolescents aged 12 to 17 years have poorer EF skills and day-to-day functioning 6 to 12 months after sustaining brain injury (Kurowski et al., 2013) and children who sustain a brain injury at less than 7 years old will have significant EF difficulties 5 years later typically only if the injury is serious (Nadebaum, Anderson, &amp; Catroppa, 2007). Skills that develop soonest are left more intact for all early injury severities (Nadebaum et al., 2007), whereas effects can apparently worsen for higher level EF skills that develop later and become “natural” expectations (Powell &amp; Voeller, 2004). Where brain injury is more severe, effects on each of the 3 components have been identified (Levin &amp; Hanten, 2005).</td>
</tr>
<tr>
<td>Cognitive issues:</td>
</tr>
<tr>
<td>- children with language difficulties. This has been explored in children with hearing loss (Hintermair, 2013) and specific language impairment (SLI) (Wittke, Spaulding &amp; Schechtman, 2013). Those with SLI seem to have a particular difficulty with Working Memory (Vugs, Hendriks, Cuperus, &amp; Verhoeven, 2014).</td>
</tr>
<tr>
<td>Affect issues:</td>
</tr>
<tr>
<td>- children who are anxious. This has been shown by inducing anxiety and negative mood in children; their performance becomes poorer especially on Inhibition tasks, such as Stroop (Pnevmatikos &amp; Trikkaliotis, 2013). This fits with evidence from adults that mental health problems are associated with EF difficulty (Bagney et al., 2013) that could be a principal mediator of associated psychological impairment (McIntyre et al., 2013).</td>
</tr>
</tbody>
</table>
Developmental conditions:
- those with a diagnosis of ADHD. EF deficit is generally regarded to be a core issue with ADHD (Hedges, 2010). Nevertheless the picture is not straightforward, standardised neuropsychological tests of EF identify boys with a diagnosis with 73% accuracy and girls with a diagnosis with 79% accuracy; parent ratings are more accurate (Skogli, Teicher, Andersen, Hovik, & Oie, 2013). Cao et al. (2013) examined inhibitory control and found that although associated ERPs and ability to monitor task conflicts were similar whether or not children had ADHD, the children with ADHD had greater difficulty with Inhibition behaviours. Qian, Shuai, Chan, Qian, & Wang (2013) studied 7 to 15 year olds and found Inhibition and Shift skills were about 2 years behind in children with ADHD, but that Working Memory and planning skills were fine.

- those with a diagnosis of Autism. Again the picture is not straightforward. Children aged 8 with more severe autism find that Shifting i.e. the ability to be flexible is particularly difficult (Reed, Watts, & Truzoli, 2011). Children of a similar age within a sub-category of Autism more likely to develop psychotic symptoms over time have relatively greater EF impairment, especially for attention and Inhibition (van Rijn et al., 2013). By contrast, Sachse et al. (2013) find that most EF is intact in high functioning adolescents and adults with Autism; they just process information somewhat more slowly. However, Rosenthal et al. (2013) find that real-world metacognitive EF is increasingly relatively impaired as higher functioning children with Autism move into adolescence and beyond.

- those with a diagnosis of learning difficulty. EF deficit is less where the learning difficulty is mild and more where it is moderate, as measured by teacher ratings on the BRIEF (Memisevic & Sinanovic, 2014).

Environment issues:
- where measures of Inhibition capture the ability to suppress interference (as opposed to inhibiting responses) bi-lingual pre-schoolers show greater Inhibition skills (Esposito, Baker-Ward, & Mueller, 2013).
- those who start to regularly smoke marijuana before the age of 16, not only smoke more as adults, but have poorer EF as adults (Gruber, Sagar, Dahlgren, Racine, & Lukas, 2012)
- parents’ ability to scaffold problem-solving at age 2 and 3 is associated with better EF at age 4. Some of the improvement is mediated by improved language at age 3. (Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012). (Types of interaction are differently associated with 3 year olds’ EF levels, use of direction appearing to be less useful (Bindman, Hindman, Bowles, & Morrison, 2013))
- infants’ frontal brain activity at 10 months and their mothers’ positive affect at that time both (jointly and uniquely) predict EF at age 4 (Kraybill and Bell, 2012)
- children with prenatal exposure to toxic substances. Adolescents with prenatal exposure to cocaine and/or alcohol show differences in white matter structure in specific brain areas; the extent of these differences is negatively correlated with EF measures (Lebel et al., 2013). Twelve year olds prenatally exposed to cocaine have poorer EF skills (Minnes et al., 2014).
- children who have experienced early adversity, especially of institutional care (McDermott et al., 2013; Merz, McCall, Wright, & Luna, 2013). These effects can last at least into the teenage years, despite adoption before the age of two (Merz et al., 2013). Less extremely, negative caregiving behaviour still seems to account for some unique EF variance at 36 months (Cuevas et al., 2014).
- children exposed to more cumulative hours of television that started at a younger age have poorer EF skills, although the type of television watched has a mediating effect (Nathanson, Aladé, Sharp, Rasmussen, & Christy, 2014). Lillard & Peterson (2011) found that just 9 minutes of fast-paced TV cartoon had an immediate (though probably short term) negative effect on EF in 4 year olds.
### Appendix 2.6: Research papers describing interventions for general EF

#### Table A2.8: Research on interventions for general EF

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study type</th>
<th>Intervention tool</th>
<th>Setting</th>
<th>Age group</th>
<th>Outcome and effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almas et al. (2012)</td>
<td>Randomised controlled study.</td>
<td>Foster care program (versus staying in institutional care or never having been in care).</td>
<td>Care settings in Bucharest</td>
<td>Children aged 8 years (Romanian orphans)</td>
<td>At eight years old, those removed before 20 months had similar teacher rated social skills and EEG patterns to children who had never been in care. Those removed after 20 months fared less well. (No effect sizes given.)</td>
</tr>
<tr>
<td>Best (2012)</td>
<td>Quantitative experimental within-subjects design (4 conditions), with convenience sample.</td>
<td>Video games with higher and lower levels of physical activity and cognitive challenge.</td>
<td>Half in primary school after school club and half in a University laboratory.</td>
<td>33 pre-adolescent children, aged 6 to 9 years</td>
<td>Physical activity, but not cognitive engagement improved performance on the Flanker task, via efficiency in resolving visuospatial conflict. Small effect sizes.</td>
</tr>
<tr>
<td>Bierman, Nix, Greenberg, Blair, &amp; Domitrovich (2008)</td>
<td>Randomised controlled study.</td>
<td>School readiness program</td>
<td>Pre-school</td>
<td>356 children, 4 years old split into two groups including control</td>
<td>Some aspects of EF were boosted. In turn these mediated school readiness. (No effect sizes given.)</td>
</tr>
<tr>
<td>Byun et al. (2014)</td>
<td>Quantitative experimental within-subjects design (two conditions).</td>
<td>Mild acute exercise</td>
<td>University laboratory</td>
<td>25 young adults</td>
<td>Stroop performance improved with exercise; authors suggest this was due to heightened arousal leading to more intense activity in PFC. (No effect sizes given.)</td>
</tr>
<tr>
<td>Chang, Tsai, Chen, &amp; Hung (2013)</td>
<td>Quantitative quasi-experimental, between-subject design.</td>
<td>Physical activity, mild or moderate, 35 minutes twice each week, for 8 weeks.</td>
<td>School setting</td>
<td>26 children, aged 6 to 7½ years.</td>
<td>Improved performance on Flanker task (no effect sizes given) and ERP changes were consistent with EF improvement.</td>
</tr>
<tr>
<td>Authors</td>
<td>Study type</td>
<td>Intervention tool</td>
<td>Setting</td>
<td>Age group</td>
<td>Outcome</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------</td>
<td>--------------------------------------------------------</td>
<td>------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Crova et al. (2014)</td>
<td>Randomised controlled study.</td>
<td>Physical activity with or without cognitive challenge</td>
<td>School</td>
<td>70 children aged 9 to 10 years split into two groups including control</td>
<td>Fitter children consistently showed better EF. EF in overweight children improved relatively more if the programme involved physical activity with cognitive challenge. (No effect sizes given.)</td>
</tr>
<tr>
<td>Diamond, Barnett, Thomas &amp; Munro (2007)</td>
<td>Randomised controlled study.</td>
<td>Curriculum approach called TOOLS.</td>
<td>Pre-schools</td>
<td>147 children, average age 5.1 years, split into two groups including active control</td>
<td>Children in settings using TOOLS outperformed others on Dots and Flanker tasks, the effect being more pronounced on the hardest tasks. (No effect sizes given.)</td>
</tr>
<tr>
<td>Dawson et al. (2014)</td>
<td>Randomised controlled study.</td>
<td>Metacognitive strategies</td>
<td>Mixture of research institute and participants’ homes – for all participants.</td>
<td>22 older adults with typical age-related cognitive impairment split into two groups including control</td>
<td>No measureable effect on EF, but positive qualitative changes in perceptions of day-to-day functioning such as coping with new situations and taking exercise regularly.</td>
</tr>
<tr>
<td>Gothe, Pontifex, Hillman, &amp; Mcauley (2013)</td>
<td>Repeated measures experimental design, with convenience sample excluding regular practitioners of Yoga or other mind-body based exercise.</td>
<td>Yoga versus aerobic exercise</td>
<td>Exercise room in University</td>
<td>30 healthy young women, average age 20 years</td>
<td>Aerobic exercise had little effect on EF (Flanker and Nback tasks), whereas Yoga had significant moderate or large effects, particularly on accuracy.</td>
</tr>
<tr>
<td>Hahn-markowitz, Manor, &amp; Maeir (2011)</td>
<td>Simple, quasi-experimental pre-, post- measures design, with convenience sample from children attending clinic.</td>
<td>CogFun OT programme that focuses on cognitive strategies for day-to-day occupational performance.</td>
<td>Clinic</td>
<td>17 children with ADHD, aged 7-8 years</td>
<td>Scores improved on BRIEF and Tower of London task, with moderate and large effects respectively. There was some maintenance at 3 months.</td>
</tr>
<tr>
<td>Authors</td>
<td>Study type</td>
<td>Intervention tool</td>
<td>Setting</td>
<td>Age group</td>
<td>Outcome</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-------------------------------------</td>
<td>------------------------------------</td>
<td>------------</td>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hung, Tsai, Chen, Wang, &amp; Chang (2013)</td>
<td>Between subject, quasi-experimental design, with convenience sample of volunteers responding to flyers.</td>
<td>Acute exercise</td>
<td>Laboratory</td>
<td>40 healthy young adults, in early 20s split into two groups including control</td>
<td>Planning skills, as measured by the Tower of London task, were improved for up to an hour and there were less impulsive decisions. The significant main effect of time and the interaction of group x time had large and moderate effect sizes respectively.</td>
</tr>
<tr>
<td>Kam, Greenberg, &amp; Kusche (2004)</td>
<td>Randomised control trial (of classes)</td>
<td>PATHS programme</td>
<td>School</td>
<td>133 8 year olds with some learning difficulties split into two groups including control</td>
<td>Improvements in behaviour (less challenging) (small teacher rated effect) and reduced symptoms of depression (moderate self-rated effect).</td>
</tr>
<tr>
<td>Kamijo &amp; Takeda (2010)</td>
<td>Between subject, quasi-experimental design, with convenience sample of university students grouped according to regular exercise levels.</td>
<td>Existing physical activity pattern.</td>
<td>University</td>
<td>40 healthy young adults, average age 21.4 years.</td>
<td>For switch tasks requiring more executive control, the physically active group did better. The effect size was small. Direction of causality was assumed but not proved.</td>
</tr>
<tr>
<td>Kesler et al. (2013)</td>
<td>Randomised control trial from convenience sample of breast cancer survivors. (Authors note typical negative effect of treatment on EF, especially of chemotherapy.)</td>
<td>Lumos Lab computer training: 48 sessions of 15 to 90 minutes, over 12 weeks.</td>
<td>Home setting: training done online</td>
<td>41 women aged 40 plus, on average 6 years after end of treatment, split into two groups including control</td>
<td>EF skills improved, as measured by for example, WCST and BRIEF ratings scales. Effects sizes small or moderate (d = 0.14-0.87).</td>
</tr>
<tr>
<td>Lakes et al. (2013)</td>
<td>Classes randomly assigned to regular PE or Taekwondo.</td>
<td>Regular PE lessons were compared with Taekwondo</td>
<td>School</td>
<td>Adolescent children aged 12 – 13, 75 per group.</td>
<td>Both produced a benefit for EF and parent ratings of behaviour, but Taekwondo produced greater change (the effect size was moderate to large) and some changes were significant.</td>
</tr>
<tr>
<td>Authors</td>
<td>Study type</td>
<td>Intervention tool</td>
<td>Setting</td>
<td>Age group</td>
<td>Outcome</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Manly &amp; Murphy (2012)</td>
<td>Review of previous research.</td>
<td>Various interventions including computerised Working Memory training.</td>
<td>Various rehabilitation settings</td>
<td>Adults with acquired brain injury, including stroke.</td>
<td>Training of EF components has limited useful results, mainly because of lack of generalisation. Compensatory strategies show greater benefit; environmental modifications such as automated reminders give the most benefit of all.</td>
</tr>
<tr>
<td>McCrea, Mueller, &amp; Parrila (1999)</td>
<td>Quantitative quasi-experimental, between subject (contiguous cohorts) design.</td>
<td>Formal schooling per se</td>
<td>School</td>
<td>115 children, aged 7 to 9 years</td>
<td>Positive effects (small to moderate effect size) on several measures of EF.</td>
</tr>
<tr>
<td>McDermott, (2012, 2013)</td>
<td>Randomised controlled study (with additional control group who had never been in care).</td>
<td>Foster care program (versus staying in institutional care). Age of fostering not given.</td>
<td>Care settings in Bucharest.</td>
<td>136 children recruited into studies at 2.5-4.5 years (Romanian orphans)</td>
<td>EF (performance on GO/NOGO) at 8 years was poorest for those still in institutional care, whilst ERP recordings and Flanker task scores implied reduced attentional skills in all who had experienced adversity. (No effect sizes given.)</td>
</tr>
<tr>
<td>Moreno et al. (2011)</td>
<td>Matched, between participant quasi-experimental design.</td>
<td>Computerised training programme for music. Control group had visual arts computerised training programme.</td>
<td>School – the training was in small groups, led by a teacher.</td>
<td>64 children aged 4 to 6 years split into two groups including active control</td>
<td>EF improved as measured by GO/NOGO task, but as an interaction (small effect size) not a group main effect.</td>
</tr>
</tbody>
</table>

---

8 This parallels the work of this researcher who, in work as an EP, gives a guarded recommendation regarding Working Memory boosting, but often suggests the use of Key Visuals amongst other environmental strategies.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Study type</th>
<th>Intervention tool</th>
<th>Setting</th>
<th>Age group</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miranda, Presentación, Siegenthaler, &amp; Jara (2013)</td>
<td>RCT</td>
<td>CBT in small group, with focus on social skills, problem solving and anger management, plus parent/teacher training on parallel strategies for behaviour management.</td>
<td>Health care centre.</td>
<td>42 children aged 7 – 10 years with ADHD, split into two groups including control</td>
<td>Improvements in planning and some aspects of memory and EF behaviour ratings by teachers and parents. (Mixture of small and moderate effects.)</td>
</tr>
<tr>
<td>Niemann et al. (2013)</td>
<td>Randomised control trial</td>
<td>Intense physical activity for 12 minutes</td>
<td>Not reported.</td>
<td>42 9 to 10 year olds split into two groups including control</td>
<td>Regardless of fitness level (ie habitual level of physical activity), performance on sustained and selective attention tasks improved. (No effect sizes given for theses measures.)</td>
</tr>
<tr>
<td>Nouchi et al. (2013)</td>
<td>Randomised control trial of non-gaming volunteers recruited through advertisement in local paper.</td>
<td>Brain train games (Brain Age) for about 5 minutes per day, at least 5 times each week, for 4 weeks.</td>
<td>Home</td>
<td>32 healthy young adults split into two experimental groups</td>
<td>EF and Working Memory significantly improved as measured by WCST, Stroop and WAIS processing skill tasks (small effect sizes).</td>
</tr>
<tr>
<td>Riggs, Greenberg, Kusche &amp; Pentz (2006)</td>
<td>Randomised controlled study, by school not pupil.</td>
<td>PATHS programme</td>
<td>Primary schools</td>
<td>318 pre-adolescents, aged 7 to 9 years, split into two groups including control</td>
<td>Improvement in inhibitory control, verbal fluency and social competency skills. (Analysis did not address effect sizes.)</td>
</tr>
<tr>
<td>Salminen, Strobach &amp; Schuberg, 2012</td>
<td>Randomised control trial.</td>
<td>Computerised Working Memory training</td>
<td>University laboratory</td>
<td>38 young adults (university students) split into two groups including control</td>
<td>Performance improved on Working Memory, attentional processing and switch tasks (mixture of moderate and large effect sizes).</td>
</tr>
<tr>
<td>Authors</td>
<td>Study type</td>
<td>Intervention tool</td>
<td>Setting</td>
<td>Age group</td>
<td>Outcome</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------</td>
<td>--------------------------------------------------------</td>
<td>----------------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Shatil, Mikulecká, Bellotti, &amp; Bureš (2014)</td>
<td>Randomised control trial.</td>
<td>TV-based interactive cognitive training programme</td>
<td>Mostly in university laboratories, but some adults did at home</td>
<td>119 older adults (60 – 87 years) split into two groups including control</td>
<td>Performance on Working Memory and EF measures increased, but there were no perceived day-to-day benefits. (No effect sizes given.)</td>
</tr>
<tr>
<td>Steiner, Frenette, Rene, Brennan, &amp; Perrin (2014)</td>
<td>Randomised controlled study.</td>
<td>Computer-based attention training using neurofeedback vs. cognitive training. 45 minute sessions, 3 times per week to a total of 40 sessions over 5 months</td>
<td>School</td>
<td>104 children 7 – 11 years with ADHD split into three groups including control</td>
<td>Neurofeedback group showed significant benefits on several measures (small effect sizes); cognitive training group showed more limited benefits. Measures included BRIEF and Connors ratings scales.</td>
</tr>
<tr>
<td>Stern, Blumen, Rich, Herzberg, &amp; Gopher (2011)</td>
<td>Randomised controlled study.</td>
<td>Complex video game. 36, 1 hour sessions over 3 months</td>
<td>Home</td>
<td>60 healthy older adults (mean age approx. 65) split into three groups including control</td>
<td>Just one of three measures showed improvement, a Working Memory sequencing task. Showed crucial features are: intensity and increasing difficulty. (No effect sizes given.)</td>
</tr>
<tr>
<td>Stroth et al. (2009)</td>
<td>Within subjects experimental design</td>
<td>Long term fitness and acute exercise</td>
<td>Fitness was assessed within regular PE lessons and intervention/measures took place at a laboratory.</td>
<td>35 adolescents, 13 – 14 years</td>
<td>Fitness level rather than acute exercise seemed to improve cognitive function. Brain activity whilst doing the Flanker task suggested fitness level improves EF efficiency, with more “preparation” brain activity and less brain activity then needed during the task. (No effect sizes given.) (Gives useful detail of ERP waveforms.)</td>
</tr>
<tr>
<td>Authors</td>
<td>Study type</td>
<td>Intervention tool</td>
<td>Setting</td>
<td>Participants</td>
<td>Outcome</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>---------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Tamm, Nakonezny, &amp; Hughes (2014)</td>
<td>Pre- and post-measures quasi experimental design</td>
<td>Sessions for children and parents in parallel, with metacognitive focus</td>
<td>Medical centre</td>
<td>24 children aged 3 - 7 years with ADHD</td>
<td>EF improved: direct measures and parent ratings, except on measures capturing Inhibition. Effect sizes were small and moderate.</td>
</tr>
<tr>
<td>Voss et al. (2010)</td>
<td>RCT</td>
<td>Aerobic (walking) vs non-aerobic (flexibility, toning and balance) exercise</td>
<td>Supervised group sessions</td>
<td>65 older adults (55 to 80 years) who were relatively inactive in previous 6 months plus younger adult control group</td>
<td>fMRI scans for both groups looked more like younger adults in some areas. Walking group showed changes in Frontal Executive connectivity especially after 12 months (not so much at 6). Extent of change was linked to modest EF improvements (limited effect sizes and significance levels).</td>
</tr>
<tr>
<td>Weiland &amp; Yoshikawa (2013)</td>
<td>Matched between subjects design. (Control group children were receiving other care at home or other nonrelative care.)</td>
<td>Classroom quality eg evidence based currm and teacher training</td>
<td>Pre-school</td>
<td>Total of 2018 preschoolers, 4 and 5 years olds</td>
<td>Moderate to large significant effect sizes for educational outcomes and small (less than expected) effect sizes with mixed significance levels for EF.</td>
</tr>
</tbody>
</table>
Appendix 2.7: Examples of research exploring EF component development

Table A2.9: Research exploring EF component development

<table>
<thead>
<tr>
<th>Authors and nature of paper</th>
<th>Area of EF covered</th>
<th>Comment and detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best et al. (2009) – a review using Miyake et al. (2000) model</td>
<td>Inhibition</td>
<td>The authors note that EF is more vulnerable to the effects of ageing than for example vocabulary, procedural memory and numeric ability and that effects are very noticeable by 70s. Also note that there is much development after five years especially of shift, working memory and planning skills. In younger children inhibition skills account for EF performance, and this changes to working memory (and some shift) in older children as inhibition becomes matured.</td>
</tr>
<tr>
<td></td>
<td>Working memory</td>
<td>There is striking development of inhibition in the preschool years and significant improvements between the ages of 5 to 8. There is disagreement about later development with some authors saying none after eight years and some reporting up until 15 years or even early adult hood. Seems depend partly on the subtlety of measures. Brain development parallels inhibition development with activity becoming more localised and connectivity increasing.</td>
</tr>
<tr>
<td></td>
<td>Shift</td>
<td>If sufficiently sensitive measures are used then working memory development can be detected through to early adult hood. Corresponding areas of brain activity change throughout childhood and adolescence.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Young children can do simple tasks. Shift develops until at least early adolescence if measures include not just simple accuracy but also efficiency. Where the rules are more numerous/complex, performance develops into adolescence; can see activation increase in inferior frontal, parietal and anterior cingulate regions. Brain activity is shown to increase in some particular areas to at least 17.</td>
</tr>
<tr>
<td>Best &amp; Miller (2010) – review</td>
<td>3 component evidence</td>
<td>Comment that assessing model/component validity is difficult across ages, since tasks are rarely suitable for all ages and some of what is measured is the task variance in other skill areas. Also that 3 component model could itself have a developmental trajectory.</td>
</tr>
<tr>
<td></td>
<td>Inhibition</td>
<td>Mixed evidence at youngest ages, although cite Hughes (1998) who give evidence for more than one component in pre-schoolers and Huizinga, Dolan and Van der Molen (2006) that at least 2 components are stable by 7 years.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Big improvements up to age 5. Evidence thereafter is mixed – dependent to some extent on the task. For example, stopping a task is harder than not starting one. Conclude that basic inhibition is well developed before 8, and that further improvements could be in the way inhibition is combined with other skills. Brain development moves from being relatively global in a baby to localised medial-frontal activity by 8; then continued localisation until adulthood. Later, changes in neural activity are seen behaviourally as subtle improvements regarding efficiency/effort needed. (NB Inhibition = interference control, cognitive inhibition and motor inhibition.)</td>
</tr>
<tr>
<td>Authors and nature of paper</td>
<td>Area of EF covered</td>
<td>Comment and detail</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Best &amp; Miller (2010) – review continued</td>
<td>Working memory</td>
<td>Again issues regarding task impurity, different kinds of working memory etc. The authors suggest that simple storage tasks such as DSF are not really EF tasks. There are improvements linearly up to 14 to 16 years (depending on the research tasks – and with task complexity determining the age of mastery); then there is some levelling off. Brain development is the specialisation of circuitry, extends into 20s with limited observable performance change in later years. Simplest Shift tasks can be performed by pre-schoolers. There is a big improvement in skill at age 5 to 6, but there are measurable improvements to age 15. In terms of brain development, there is an increase in activity in some areas and a decrease in others, the increases reflecting conflict monitoring processes (in the ACC). More detail on page 1652. (Suggest that all but the most carefully thought out tasks will need working memory and inhibition too – so the brain will be active in corresponding PFC areas.)</td>
</tr>
<tr>
<td>Brocki &amp; Bohlin (2004)</td>
<td>3 dimensional model at 6 years</td>
<td>These authors conclude that there is evidence for a three component model of EF from six years, the components being: disinhibition, working memory/fluency and speed/arousal. They see the interplay between inhibition and working memory as key to EF development.</td>
</tr>
<tr>
<td>Crone, Donohue, Honomichl, Wendelken, &amp; Bunge (2006)</td>
<td>Switch</td>
<td>Studied 8 – 12 years, 13 – 17 years and 18 – 25 years doing switch task with cued, but unpredictable Shift task whilst having fMRI scans. Errors and reaction times showed improvement across age groups, though some differences were not significant. Argued that switch tasks need: - rule retrieval/representation and found that corresponding brain activity matures later, with changes between all groups studied in VLPFC (and so imply not yet mature in 13-17 group). - task-set suppression/switch and found that corresponding brain activity matures sooner, with middle group having adult levels of activity in the pre-SMA/SMA cortex.</td>
</tr>
<tr>
<td>Dumontheil, Hassan, Gilbert, &amp; Blakemore (2010)</td>
<td>Inhibition Thought manipulation and task switch</td>
<td>Small improvements between 11 and 30 years. Greater improvements extending into late adolescence. Brain regions used didn’t change but was some reduction in activity. Improvements on tasks shown not to be due purely to structural brain changes, so likely that better strategies are used.</td>
</tr>
<tr>
<td>Durston &amp; Casey, (2006) - review</td>
<td>Development of cognitive control</td>
<td>This is protracted into adolescence and occurs alongside brain activity changes (relatively diffuse to more localised) especially in the frontal cortex.</td>
</tr>
<tr>
<td>Authors and nature of paper</td>
<td>Area of EF covered</td>
<td>Comment and detail</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------</td>
<td>--------------------</td>
</tr>
</tbody>
</table>
| Ezekiel, Bosma, & Morton (2013) | Shift as per DCCS task. | They re-analysed fMRI data of lab expt using:  
- DCCS task - a cued-switch version on a PC. (Fixation point, then cue and then stimulus.)  
- 27 volunteers (adults ~ 21 – 25 years and children 11-12 years – not many as expensive procedure)  
Note that there is  
- mixed evidence around idea that changes with age in lateral pre-frontal cortex underly changes in DCCS performance.  
- activity in many places beyond lateral PFC when Switch tasks are performed  
Both groups did worse on Switch trials (as measured by accuracy and reaction time). Reaction times were comparable between groups, but accuracy approaching significant difference.  
A common frontoparietal cognitive control network showed greater activity for both groups during switch. Areas showing connectivity to this network showed difference, implying perhaps qualitatively differences to approaches between adolescents and adults. Conclude that age related differences in brain activity for Switch tasks can be found in LPFC connectivity rather than activation per se. |
| Kok et al., (2014) | General EF but especially Inhibition | A shorter Corpus Callosum in infancy is associated with greater EF problems in pre-school, especially inhibition. This effect can be moderated by a positive discipline style, as observed at 4 years. |
| Luna, Padmanabhan, & O’Hearn (2010) – review | Response inhibition | Infants shows some ability to inhibit but it takes time for this skill to become efficient.  
Inhibition as measured by the anti-saccade paradigm shows improvement to mid or late adolescence, but a “spike” in adolescents’ brain activity in the DLPFC suggests they need more effort than adults to achieve the same results and they also do not achieve the same response rates. Development in adolescence of brain circuitry used to establish a response set (ie sustained focused attention), may underlie adolescent inhibition improvement. That is, it is not that a new cognitive ability that is emerging(inhibition) but rather the ability use it flexibly and consistently.  
Working memory has protracted development through adolescence although the basic mechanisms are available in early childhood. What is developing appears to be precision, monitoring and the ability to control distractions. The same peak in DLPFC activity is seen here for adolescent performance (as seen with their inhibition performance). Reviewing much of their own work the authors provide evidence that later development is about being more efficient and a complex interplay between the component skills of inhibition and memory. They suggest that later development involves engagement of distributed but functionally specialised circuitry in a way that is consistent with increased focus (Durston & Casey, 2006). |
Appendix 2.8: Outlines of key Switch task papers

1. Davidson et al. (2006)

This is a complex piece of research using two main computer-based paradigms, task switch and a Simon (Inhibition) task, that were given in several forms so as to manipulate Working Memory requirements. The 325 participants ranged in age from 4 to 45, with about 30 in each year group from 4 to 13 and also 20 adults. The study is useful for showing how tasks can have skill loadings manipulated. Their tasks were as follows:

<table>
<thead>
<tr>
<th>MEMORY LOAD</th>
<th>INHIBITORY CONTROL DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Dots-Congruent</td>
</tr>
<tr>
<td>Medium</td>
<td>Dots-Incongruent,</td>
</tr>
<tr>
<td></td>
<td>Pictures</td>
</tr>
<tr>
<td>High</td>
<td>2-Nontraid-Shapes</td>
</tr>
<tr>
<td></td>
<td>Dots-Mixed</td>
</tr>
<tr>
<td></td>
<td>6-Abstract/Shapes</td>
</tr>
</tbody>
</table>

(Davidson et al., 2006, pg. 2042)

The aim of the study was to explore the interrelations and development of the 3 EF components using the several task variants.

The youngest children were able to perform basic Working Memory and response inhibition tasks, and combine these skills, so long as no shift was involved. For them, shift between task-sets seemed to be harder even for low Working Memory tasks, but these were easy for adults. Inhibition manipulations seemed to affect the younger children most in terms of switch cost effects whereas for adults the Working Memory manipulations had most effect. The cross-over appeared to be at around 10 years of age, although varying the Inhibition requirement still had some effect at 13 years. Switch costs showed up more in error rates for children and reaction times for adults; the former were more impulsive, whilst the latter took their time with harder items.

Holding two super-ordinate rules in mind and randomly switching between rules allowing or inhibiting the prepotent response (Dots Mixed) was difficult even for the adults and harder than a purer, but difficult Working Memory task (6 Shapes). Adults in general were better at juggling more EF skills within a task than children.

2. Huizinga and Van der Molen (2007)

This is an investigation of the Wisconsin Card Sorting Task (WCST), arguably a measure of general EF. The aim was to link WCST performance with the 3 EF components at different ages and as measured by more specific tasks.

For young children WCST performance was best predicted by their Inhibition and Shift skills, implying these are more varied and so developing.

For 11 year olds WCST performance was best predicted by Shift skills, Inhibition being assumed therefore to be largely developed.

For 15 year olds WCST performance was best predicted by Shift and Working Memory skills.

For 21 year olds WCST performance was best predicted by Working Memory skills, Shift being assumed therefore also to be largely developed.
Set switch aspects of WCST performance matured by about 12 years, this fitting approximately with Inhibition and Shift maturation. Set maintenance errors were seen well into adolescence, this fitting with extended Working Memory development.

3. Huizinga and Van der Molen (2011)

This research involved 7 year olds, 11 year olds and adults performing a composite Switch task: there was a cue for task-set (announcing the task to be performed) and a response cue (cuing to give or withhold a response). In line with previous research, Switch costs were higher, ie Shift was harder if:
- cue-to-item time was reduced (shorter preparation time)
- Shift was after several repeat task trials (task-set more embedded)
- Shift was to the prepotent response (in this case to re-commence responding).

Switch costs reduced with increasing age. The 7 year olds responded more when they shouldn't have, ie prepotent response Inhibition was harder, but Shifting back to the prepotent response was as difficult for them as for adults.

4. Ikeda et al. (2013)

This research was aiming to find an alternative to Stroop that would allow Inhibition to be studied in children who are too young to have developed the Stroop effect. The researchers used animal's real size as the prepotent response and picture-size (of animals) as the less dominant response. The usefulness of the paper for this research was their teasing apart of Inhibition:
- suppression of interference from stimuli (non-relevant dimensions)
- suppression of irrelevant internal thoughts (their removal from Working Memory)
- suppression of a prepotent response
- suppression of a reflexive saccade.

5. Kalanthroff and Henik (2013)

The aim of this research was to show that stimuli always provoke more than one task-set, unless they are contrived. The researchers used the Stroop paradigm with XXXX as a neutral stimulus. They distinguished between information conflict (as exists for incongruent stimuli) and task conflict (the inherent multi-dimensionality of all but neutral stimuli).

Reaction times were overall in the order: congruent < neutral < incongruent.

Congruent stimuli contain two sources of information that facilitate each other: the facilitation effect. However, participants with poor Inhibition skills showed a reversed facilitation effect (when congruent stimuli were compared with neutral stimuli); it seemed that they took longer to deal with the task conflict, which exists for congruent, but not neutral stimuli.

6. Kalanthroff et al. (2013)

This research extended the above previous, by using so called neutral words (ie not relevant to the colour dimension) as well as XXXX. The reverse facilitation effect disappeared for neutral words (such as lion) and this showed that task conflict is always induced in 'real' situations. The authors cite MRI data that fits this.
Appendix 2.9: Shift task examples

Figure A2.3: Pictures Inhibition task using Simon Effect
(Davidson et al., 2006)

This stimulus requires an incongruent response: the prepotent “same side” response is inhibited in order for the rule to be followed.

Correct animal dimension is privileged. Correct animal – task pairing is held in mind.

Press key

Other stimuli:

Similar others, also using the Simon Effect:

Arrows (Davidson et al., 2006)
“Press where the arrow is pointing”

Prepotent response required

Non-prepotent response required
There are no prepotent responses in this task, unless there has been specific prior training. Switch is between stimulus-task pair types triggered by the digit-letter stimulus. Other stimulus example:

Similar tasks:

**Flanker** (Diamond, Barnett, Thomas, & Munro, 2007)
“Name the inside shape” or “Name the triangle colour”.

**Contingency naming – letter/digit position** (see Yeniad et al., 2013)
“Name the one on the left” or “Name the letter”.

**Contingency naming – colour/shape** (Miyake & Friedman, 2012)
Has less working memory load, as cue carries meaning.
“If S say the shape, if C say the colour.”
Figure A2.5: Example of colour/shape composite Switch-task
(Huizinga & Van der Molen, 2011)

Rules are given beforehand and must be remembered, but simultaneous flanking cues serve as reminders. “If the item is at the top of the screen indicate the shape: left key for circle, right key for triangle. If the item is at the bottom of the screen indicate the colour: left key for blue; withhold your response for yellow.” Stimulus dimensions: shape, colour, location.

Simon effect is avoided by showing the stimulus mid-screen.

The prepotent response in this task is to press a key, i.e. to respond. Switch (cued by stimulus location) involves both a S-task-set Shift and partial response Shift (GO/NOGO depending on the colour).

Figure A2.6: Switch task using Stroop-Effect
(Kalanthroff and Henik, 2013)

<table>
<thead>
<tr>
<th>Congruent stimulus example</th>
<th>Incongruent stimulus example</th>
<th>Neutral stimulus examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Blue</td>
<td>Horse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XXX</td>
</tr>
</tbody>
</table>

Other versions:

- Animal Stroop

- Number Stroop

Press key, if appropriate.
Appendix 2.10: Diagrammatic summaries of additional research areas

Figure A2.7: Principles offered by The Learning Hierarchy research

Learning a skill is not an all-at-once process. It can be thought of in acquisition stages:

**Acquisition**: leads to reasonably accurate performance. Is promoted by modelling, demonstration, prompting, cuing and immediate feedback. (Research on whether making mistakes during learning is useful is mixed: Potts, Eshleman, and Cooper (1993) suggest that being quick and making mistakes is still effective, whilst Lannie and Martens (2008) advocate a focus on accuracy before increasing speed especially if learners are self-monitoring.)

Intervention should have an initial focus on accuracy, with opportunities for modelling and immediate feedback.

**Fluency**: leads to rapid, accurate performance. Is promoted by drill and reinforcement.

Intervention should have similar tasks available for drill. Feedback should provide reinforcement.

**Generalisation**: leads to use of the skill in multiple settings without prompting. Is promoted by practice in multiple settings.

Intervention should allow skills usage within different task types.

**Adaptation**: leads to modified performance in response to new environmental demands. Is promoted by problem-solving practice in different settings.

Limited access to participants precludes this.

Taken from Daly, Lentz, and Boyer (1996).

Charting of progress involves measurement of performance on precise tasks, to build up a learning picture of success/error rates. This influences intervention decisions immediately. (Potts et al., 1993; Daly, Lentz, and Boyer, 1996; Ardoin & Daly, 2007)

Students’ charting of their own progress is more efficient and leads to better learning (Lannie and Martens, 2008).

Intervention should allow learners to track their own progress. Criteria should be set for when an initial emphasis on accuracy can be changed to a focus on speed with maintained accuracy.

Relevant to basic skill acquisition. Hence is typically used as a remedial bolt-on (Solity, 1991).

**Intervention to focus on basic EF skills**. Is still effective if a student already has some basic level of skill (Martens & Eckert, 2007).

**Intervention must allow learners to work from their existing Switch/Shift skill level**.

Task analysis determines necessary sub-skills; the learner should work on their weak areas (Raybould & Solity, 1988).

**Intervention development work to focus on component EF skill Shift**. It must also identify sub-skills needed in typical Shift tasks and include practice if seems appropriate.

Building a curriculum based on task hierarchies has little effect beyond primary school, but building fluency of basic skills produces benefit (Chiesa & Robertson, 2000; Hattie, 2009).

Careful task sequencing and spacing can enhance outcomes:

- **increasing levels of difficulty** (Martens & Eckert, 2007).
- **distributed** rather than massed practice (it enhances fluency) (Bird, 2010; Budé, Imbos, Wiel, & Berger, 2010; Hattie, 2009; Martens & Eckert, 2007; Mumford, Costanza, Baughman, Threlfall, & Fleishman, 1994); a few minutes practice each day can make a difference (Downer, 2007).
- systematic **interleaving** of different task types creates more effortful engagement (and mistakes) during learning but better performance later (Cates, 2005; Lin et al., 2011). Interleaving appears to be more beneficial where the representation methods are consistent but the tasks are interleaved (Rau, Aleven, & Rummel, 2013) and where fluency tasks are interleaved with acquisition tasks (Cates, 2005).

Intervention should involve tasks being presented in increasing difficulty order, with some interleaving and frequent, short practice opportunities.

The Learning Hierarchy (Haring & Eaton, 1978)

NB Some research used is older than 15 years: there is a lack of more recent work.
Figure A2.8: Principles offered by Flow

In a state of Flow, people:
- experience concentration, interest and enjoyment (Shernoff, Schneider, & Shernoff, 2003)
- feel cognitively efficient, happy and motivated (Moneta & Csikszentmihalyi, 1996)
- their subjective experience about a task is optimised (Moneta & Csikszentmihalyi, 1996)
- are intrinsically motivated by the feelings produced and this fosters psychological growth through further search for Flow and hence for mastering new challenges and skills (Moneta & Csikszentmihalyi, 1996; Shernoff et al., 2003).

Hence flow can be seen to represent satisfying engagement with a task that promotes learning.

**Flow likelihood**, and particularly the concentration and involvement aspects, can be maximised in educational settings (secondary and beyond) through:

a) providing tasks with an optimal balance (see * below) between perceived challenge and perceived ownership of adequate skills to meet the challenge (Moneta & Csikszentmihalyi, 1996)
b) providing structured activities within which individuals can seek the level suitable for them and know how to move forwards to make progress (Moneta & Csikszentmihalyi, 1996)
c) making instruction seem relevant (Shernoff et al., 2003)
d) giving learners control over their environment, this being perceived as happening more if working individually or in groups (Shernoff et al., 2003)
e) task competence is valued (Abuhamdeh & Csikszentmihalyi, 2012b)
f) learners giving their full attention because the tasks make them want to, through challenge and competence valuation (Abuhamdeh & Csikszentmihalyi, 2012b).

**NB Learners don’t always want Flow intensity and typically see less academic subjects as more enjoyable** (Shernoff et al., 2003).

**Intervention tasks need characteristics (a) to (f).**

*Perceived challenge vs skill balance*

<table>
<thead>
<tr>
<th>Perceived challenge level. This pertains primarily where tasks are intrinsically motivating (one would choose to engage with them for their own sake) and goal directed.</th>
<th>Perceived skill level</th>
<th>Likely outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Apathy</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>Anxiety</td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
<td>Boredom</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>Flow</td>
</tr>
</tbody>
</table>

**Intervention tasks should ideally be goal-directed and seen as fun, with mistakes as acceptable.**

(Moneta & Csikszentmihalyi, 1996)
### Comic strip conversations

- **Principles offered by comic strip conversations**

**Comic strip conversations** provide visual representations of the different levels of communication that take place in a conversation, using symbols, stick figure drawings and colour. The child/young person co-constructs the comic strip conversation.

**Useful ideas:**
- the creation of a visual system to assist understanding of a social situation
- the visual system facilitates joint attention and meaning-making
- consistent symbols and colours are used to denote thinking/talking etc (Hutchins & Prelock, 2006).

An intervention could usefully use a visual system with consistent symbols and colours to assist joint understanding, although the intention would be to impart rather than to construct meaning.
Appendix 3: Appendices for Chapter 3

Appendix 3.1: Research invitations and consent forms

Draft pupil participant information sheet and consent form

Boosting Thinking Skills
Participant Information Sheet

You are invited to take part in a research study being introduced into school by a trainee educational psychologist. The aim of the research is to develop a programme of activities that boost important thinking skills.

Before you decide to take part it is important for you to understand why the research is being done and how it will involve you. Please take time to read the following information carefully and discuss it with others, such as your parents or carers. Please ask if there is anything that is not clear or if you would like more information. One opportunity to do this will be an information evening being held in school by the researcher on ..........

Take time to decide whether or not you wish to take part. If you do, the consent form attached must be signed by you and a parent/carer and then returned to school. Thank you for reading this.

Who will conduct the research?
The researcher is Susan Darby, a trainee educational psychologist from the University of Manchester. She is based at:

School of Education
Ellen Wilkinson Building
The University of Manchester
Oxford Road
Manchester
UK
M13 9PL

Title of the research: Boosting thinking skills.

What is the aim of the research?
Scientists have found that certain thinking skills help students to do well in school. These include being able to:

- hold information in your memory
- being able to switch between tasks efficiently and
- being able to reflect on what you are doing.

The research aims to find activities that will boost some of these important thinking skills. This stage will involve a class of Year 8 students trying out some thinking skills activities in form time, to see if they benefit. About six students will also be
asked to give their detailed opinions and possibly to try out more of the activities in a small group within form time.

**Why have I been chosen?**

The hope is that the thinking skills activities will help many pupils in school. For the research to progress further it is important for a class of year 8 students to try them out and your form tutor has agreed for your class to be involved. Everyone in your class is being invited to join the research.

**What would I be asked to do if I took part?**

You would be asked to trial the activities, working in pairs during morning form time, for sessions of about 20 minutes, 3 or more times a week, for about six weeks. The research activities are intended to be enjoyable and if successful they may also allow you to improve your thinking skills!

The activities would initially be introduced by the researcher, Susan Darby, but then would be managed by a teaching assistant or your form teacher. Sometimes the researcher would attend activity sessions. In addition you would be asked to complete some thinking skills activities with the researcher before you started to use the activities in class.

After the class-based trials were finished, about six students would also be invited to give their opinions in an interview with the researcher and complete some more thinking skills tasks with her. This interview would be recorded and quotes used anonymously in research reports. Depending on how the trials went, this small group of students might be asked to continue them in a separate classroom, for up to a few weeks.

**What happens to the data collected?**

Opinions and scores from the activities completed with the researcher would be used to write part of a report about the research.

**How is confidentiality maintained?**

All information will be kept anonymously and by the researcher for up to seven years in a locked cupboard. Audio-recordings, transcript softcopies and scores data will be stored on an encrypted memory stick. Five years after the research is completely finished, the information will be destroyed: the data stick will be wiped and papers shredded.

**What happens if I do not want to take part or if I change my mind?**

It is up to you to decide whether or not to take part. You will be given this information sheet to take home to discuss and if you want to take part, you and your parents or carers must sign the consent form, to be returned to school by 31st January 2014, when the research starts.

If you decide to take part you are still free to withdraw at any time without giving a reason.

**What is the duration of the research?**
Trying out activities will take place for about six weeks, starting on 24\textsuperscript{th} February 2014.

Completing some thinking skills activities beforehand with the researcher is anticipated to take place during the week commencing 3\textsuperscript{rd} February 2014. The follow up interviews with a small group of students are anticipated to take place soon after 22\textsuperscript{nd} April 2014. The exact timing will be decided through discussion with teachers so that your normal learning will be disrupted as little as possible.

**Where will the research be conducted?**
The research will take place in school, in your form room.

**Will the outcomes of the research be published?**
If the research is successful, the outcomes may be published in education or psychology journals. Whatever happens, you will be given information by the end of this school year on how this stage of the research went.

**Criminal Records Check**
The researcher Susan Darby has undergone a recent enhanced criminal records check and has experience of working with students of your age.

**Contact for further information**
The researcher Susan Darby can be contacted by e-mail: susan.darby@postgrad.manchester.ac.uk

**What if something goes wrong?**
If you feel you need help or advice as a result of taking part in the research, you can contact the researcher Susan Darby by e-mail: susan.darby@postgrad.manchester.ac.uk.

If there are any issues regarding this research that you would prefer not to discuss with the researcher, please contact the Research Practice and Governance Co-ordinator by either writing to 'The Research Practice and Governance Co-ordinator, Research Office, Christie Building, The University of Manchester, Oxford Road, Manchester M13 9PL', by emailing: Research-Governance@manchester.ac.uk, or by telephoning 0161 275 7583 or 275 8093.
1. I confirm that I have read the information sheet on the above study and have had the opportunity to consider the information and ask questions and had these answered satisfactorily.

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason.

3. If I give feedback, I understand that the interview will be audio-recorded.

4. If I give feedback, I agree to the use of anonymous quotes.

5. I agree that any data collected may be published in anonymous form in academic books or journals.

I agree to take part in the above project.

Name of participant: ____________________________ Date: ____________ Signature: ____________________________

Name of person giving consent as parent or carer: ____________________________ Date: ____________ Signature: ____________________________
The above proposed documents for potential student participants were not accepted by the host school as appropriate. The approved documents follow, with the school logo removed; these were additionally approved by the University through the amendment process.

Participant Information Sheet

Boosting Thinking Skills – Invitation to take part in the research
You are invited to take part in some research being carried out in school by a researcher from Manchester University. This sheet tells you what the research is about. Please read it carefully and talk about it with your parents/carers at home.

If you decide that you would like to take part you need to return the signed consent form by Friday January 24th 2014. This is enclosed.

What is the research? Scientists have found that certain thinking skills help students to do well in school. These include being able to remember information, to change what you are thinking about when you need to and to reflect on what you are doing.
The research aims to find ways to boost some of these important thinking skills in students of your age, through fun activities. These include seeing how accurately and fast you can name the item on a card.

Why me and what would I do? You are in a form of students of the right age and your school has agreed to the research taking place at The Heath. All of your form has been invited to take part.
You would be trying the activities out during form time, 3 times a week, starting on the 24th February 2014, for up to 6 weeks. The hope is that you will enjoy the activities and you might become a better thinker!

Your opinions are important, so if you were happy to, you might also be interviewed at the end of the research to see what you thought of the activities.

Who will show me what to do? The activities will initially be introduced by the researcher, Susan Darby, but then will probably be managed by a teaching assistant, Mrs X or your form teacher, Mr Z. Susan has undergone a recent enhanced criminal records check and has experience of working with students of your age.
Before the 24th February 2014, Susan will visit your form to introduce the whole scheme and gather some initial information from you.

What happens afterwards? All the information gathered by the researcher will be used to write part of a report about the research. It will be used anonymously – your name will not appear anywhere.
She will also send a short report to school, that you can take home.
The information will be kept securely and destroyed once the research is completely finished.

Contact for further information. The researcher Susan Darby can be contacted by e-mail: susan.darby@postgrad.manchester.ac.uk or you can talk to Mrs X, Mrs Y or Mr Z.
We hope that you will support us in this matter and I include a consent form below.

There will be an opportunity to meet Ms Sue Darby on Monday, 20th January ’14. This will be a short meeting between 5.30pm and 6.30pm, for any parents/carers who are interested to know more about the research or who have any queries or concerns.

PUPIL CONSENT FORM

1. I would like to take part in the study and I know what is expected of me. □

2. I know that I can leave the research □

3. If I give my opinions, I understand that they:
   - will be used without my name to write reports □
   - may be audio-recorded □

Please tick the boxes to show you understand them and then sign below. One of your parents or carers needs to sign too.

**Student:**

I agree to take part in the thinking skills research.

Signature: ……………………… Date: …………. Name: ………………………

**Parent/Carer:**

I agree to take part in the thinking skills research.

Signature: ……………………… Date: …………. Name: ………………………

Please return form to Mr Z
Teaching staff participant information sheet and consent form

Boosting Executive Function skills in young adolescents

You are being invited to take part in a research study that will form part of the evidence towards my Doctorate in Child and Educational Psychology. My research aims to develop a programme of activities that boost important thinking skills, also known as Executive Function skills.

Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

Who will conduct the research?

The researcher is Susan Darby, a trainee educational psychologist from the University of Manchester. She is based at:

School of Education
Ellen Wilkinson Building
The University of Manchester
Oxford Road
Manchester
UK
M13 9PL

Title of the research: Boosting Executive Function skills in young adolescents

What is the aim of the research?

Scientists have found that certain thinking skills (also known as Executive Function skills) help students to do well in school. These include being able to:

- hold information in your memory
- being able to switch between tasks efficiently and
- being able to reflect on what you are doing.

In a first stage of the research, some activities were identified that might help with mental flexibility, ie being able to switch between tasks efficiently. These activities now require further development, so that they form a coherent package. Also, staff in a secondary school suggested factors that might affect implementation of a programme, particularly before it has proven benefits. These included a need to minimise risk to school performance indicators.
This second stage of research aims to develop a programme of activities to the point where it might be ready for a controlled trial in school. It will take the activities mentioned above and attempt to develop them into a working programme prototype and then trial them with a class of adolescent pupils.

**Why have I been chosen?**

As a Year 8 form tutor or TA who works with Year 8 pupils, you are well placed to try out the programme prototype with a Year 8 class.

**What would I be asked to do if I took part?**

Before the programme starts you would be asked to attend a group discussion for up to one hour, during which you would have the opportunity to look at the proposed materials and give your opinion on them. The conversation would be audio-recorded.

After training and some observations of initial sessions of pupils using the activities with the researcher, you would be asked to manage the programme prototype for 6 weeks, during the second half of the Spring Term 2014. It is anticipated that this would be three or more times a week within morning form time. You would be expected to feedback difficulties promptly, including issues around fitting the programme in. The researcher would attend sessions on weekly basis to see how the intervention is going and help make changes if necessary.

Once the programme is finished you would be asked for detailed feedback in an interview with the researcher. The conversation would be audio-recorded.

**What happens to the data collected?**

The audio-recordings will be transcribed anonymously and analysed for themes. These and possibly some direct anonymised quotes would be used in part of the research report.

**How is confidentiality maintained?**

The audio-recordings and transcript softcopies will be stored on an encrypted memory stick. Printed copies of transcripts will be stored in a locked cupboard. Five years after the research is completely finished, all the data will be destroyed: the data stick will be wiped and papers shredded.

**What happens if I do not want to take part or if I change my mind?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you will be asked to sign two consent forms, one regarding the discussion group and one the running of the programme.

If you decide to take part you are still free to withdraw at any time without giving a reason.
What is the duration of the research?

Trying out activities will take place for approximately six weeks, starting on 24th February 2014.

The group discussion is likely to be held in the week commencing 6th January 2014, the training in the week commencing 10th February 2014 and the feedback interview in the week commencing 22nd April 2014, at times to suit you.

Where will the research be conducted?

The research will take place in school, room details to be confirmed.

Will the outcomes of the research be published?

If the research is successful, the outcomes may be published in education or psychology journals. Whatever happens, you will be given information by the end of this school year on how this stage of the research went.

Contact for further information

The researcher Susan Darby can be contacted by e-mail: susan.darby@postgrad.manchester.ac.uk

What if something goes wrong?

If you feel you need help or advice as a result of taking part in the research, you can contact the researcher Susan Darby by e-mail: susan.darby@postgrad.manchester.ac.uk.

If there are any issues regarding this research that you would prefer not to discuss with the researcher, please contact the Research Practice and Governance Coordinator by either writing to ‘The Research Practice and Governance Coordinator, Research Office, Christie Building, The University of Manchester, Oxford Road, Manchester M13 9PL’, by emailing: Research-Governance@manchester.ac.uk, or by telephoning 0161 275 7583 or 275 8093.
CONSENT FORM FOR STAKEHOLDER FOCUS GROUP

If you are happy to participate please complete and sign the consent form below.

1. I confirm that I have read the attached information sheet on the above study and have had the opportunity to consider the information and ask questions and had these answered satisfactorily.

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason.

3. I understand that the group discussion will be audio-recorded.

4. I agree to the use of anonymous quotes.

5. I agree that any data collected may be published in anonymous form in academic books or journals.

I agree to take part in the above project.

Name of participant ___________________________ Date __________ Signature ___________________________

_____________________________ ___________________________ ___________________________
Boosting Executive Function skills in young adolescents

CONSENT FORM TO RUN INTERVENTION

If you are happy to participate please complete and sign the consent form below

Please Initial Box

1. I confirm that I have read the attached information sheet on the above study and have had the opportunity to consider the information and ask questions and had these answered satisfactorily.

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason.

3. I confirm that I have received training to prepare me to deliver the thinking skills programme

4. I understand that the feedback interview will be audio-recorded

5. I agree to the use of anonymous quotes

6. I agree that any data collected may be published in anonymous form in academic books or journals.

I agree to take part in the above project

Name of participant ___________________________ Date ______________ Signature ___________________________

_________________________ ___________________________ ___________________________
Boosting Executive Function skills in young adolescents

Expert Participant Information Sheet

You are being invited to take part in a research study that will form part of the evidence towards my Doctorate in Child and Educational Psychology. The research aims to develop a programme of activities that boost important thinking skills, also known as Executive Function skills.

Before you decide to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

Who will conduct the research?

The researcher is Susan Darby, a trainee educational psychologist from the University of Manchester. She is based at:

School of Education
Ellen Wilkinson Building
The University of Manchester
Oxford Road
Manchester
UK
M13 9PL

Title of the research: Boosting Executive Function skills in young adolescents

What is the aim of the research?

Scientists have found that certain thinking skills (also known as Executive Function skills) help students to do well in school. These include being able to:

- hold information in your memory
- being able to switch between tasks efficiently and
- being able to reflect on what you are doing.

In a first stage of the research, some activities were identified that might help with mental flexibility, i.e., being able to switch between tasks efficiently. These activities now require further development, so that they form a coherent package. Also, staff in a secondary school suggested factors that might affect implementation of a
programme, particularly before it has proven benefits. These included a need to minimise risk to school performance indicators.

This second stage of research aims to develop a programme of activities to the point where it might be ready for a controlled trial in school. It will take the activities mentioned above and attempt to develop them into a working programme prototype and then trial them with a class of adolescent pupils.

**Why have I been chosen?**

As an educational psychologist with a research interest in Executive Function, your opinions during the development of a programme would be really useful to help guide the process. The intention is to have two experts discuss each phase.

**What would I be asked to do if I took part?**

You would be asked to attend up to three small group discussion sessions for up to one hour each, during which you would have the opportunity to look at particular aspects of the development process and give your opinion on them. The conversation would be audio-recorded.

**What happens to the data collected?**

The audio-recordings will be transcribed anonymously and analysed for themes. These and possibly some direct anonymised quotes would be used in part of the research report.

**How is confidentiality maintained?**

The audio-recordings and transcript softcopies will be stored on an encrypted memory stick. Printed copies of transcripts will be stored in a locked cupboard. Five years after the research is completely finished, all the data will be destroyed: the data stick will be wiped and papers shredded.

**What happens if I do not want to take part or if I change my mind?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you will be asked to sign a consent form.

If you decide to take part you are still free to withdraw at any time without giving a reason.

**Will I be paid for participating in the research?**

Unfortunately it will not be possible to pay participants or reimburse expenses. To minimise costs, an effort has been made to choose a convenient location. Refreshments will be provided.

**What is the duration of the research?**
The three discussions will take place between 4\textsuperscript{th} November 2013 and 10\textsuperscript{th} January 2014 at times to suit you.

**Where will the research be conducted?**

The first two discussion groups will be held at the University of Manchester, room details to be confirmed. The third will be held in the school hosting this research, room details to be confirmed.

**Will the outcomes of the research be published?**

If the research is successful, the outcomes may be published in education or psychology journals. Whatever happens, you will be given information by the end of this school year on how this stage of the research went.

**Contact for further information**

The researcher Susan Darby can be contacted by e-mail: susan.darby@postgrad.manchester.ac.uk

**What if something goes wrong?**

If you feel you need help or advice as a result of taking part in the research, you can contact the researcher Susan Darby by e-mail: susan.darby@postgrad.manchester.ac.uk.

If there are any issues regarding this research that you would prefer not to discuss with the researcher, please contact the Research Practice and Governance Co-ordinator by either writing to 'The Research Practice and Governance Co-ordinator, Research Office, Christie Building, The University of Manchester, Oxford Road, Manchester M13 9PL', by emailing: Research-Governance@manchester.ac.uk, or by telephoning 0161 275 7583 or 275 8093
If you are happy to participate please complete and sign the consent form below

1. I confirm that I have read the attached information sheet on the above study and have had the opportunity to consider the information and ask questions and had these answered satisfactorily.

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason.

3. I understand that the group discussions will be audio-recorded

4. I agree to the use of anonymous quotes

5. I agree that any data collected may be published in anonymous form in academic books or journals.

I agree to take part in the above project

Name of participant __________________________ Date __________________________ Signature __________________________

_____________________________ __________________________ __________________________
Introductory email:

Dear …

As you know I am continuing my research into the possibility of boosting the shift component of EF in young adolescents. To ensure I stay on track I need to recruit some experts in the field, such as you, to attend between one and three meetings to discuss how my intervention development work is progressing. The proposed meetings are as follows:

1. A discussion of underpinning theoretical development, to be held in the week commencing 04/11/13, probably at Manchester University, although the venue and precise timing are negotiable.
2. A discussion regarding emerging intervention tasks, to be held in the week commencing 02/12/13, again probably at Manchester University, although the venue and precise timing are again negotiable.
3. A discussion regarding a first version prototype package with a wider group of stakeholders, to be held in the week commencing 06/01/14 at the hosting school, in Cheshire, details to be confirmed.

I would be grateful if you would reply indicating which, if any, meetings you feel able to contribute to.

………………..
Appendix 3.2: Detailed research schedule and operational risk analysis

Table A3.1: Timeline and time budget

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Main Activity</th>
<th>Completed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>Ethics approval</td>
<td>03/09/13</td>
</tr>
<tr>
<td></td>
<td>Write up of materials pre-pilot</td>
<td>16/09/13</td>
</tr>
<tr>
<td></td>
<td>Conduct systematic literature search, so as to meet criteria for write-up and to widen scope of review</td>
<td>30/09/13</td>
</tr>
<tr>
<td></td>
<td>Set up further literature up-date services</td>
<td>30/09/13</td>
</tr>
<tr>
<td></td>
<td>Read/re-visit literature relevant to development of programme tasks</td>
<td>25/10/13</td>
</tr>
<tr>
<td></td>
<td>Propose model for programme effectiveness</td>
<td>04/11/13</td>
</tr>
<tr>
<td></td>
<td>Construct matrix for potential programme tasks and slot in existing tasks</td>
<td>04/11/13</td>
</tr>
<tr>
<td></td>
<td>Make contact with school to generate interest in research and identify all adult participants</td>
<td>09/11/13</td>
</tr>
<tr>
<td></td>
<td>Finalise choice of and acquire tests/record booklets for pre- and post- measures</td>
<td>09/12/13</td>
</tr>
<tr>
<td></td>
<td>Develop new tasks and/or rules for existing tasks so that matrix has sufficient coverage, taking into account age of participants and proposed length of intervention</td>
<td>29/11/13</td>
</tr>
<tr>
<td></td>
<td>Develop programme to prototype stage</td>
<td>06/01/14</td>
</tr>
<tr>
<td></td>
<td>Finalise participant information sheets, consent forms and interview schedules</td>
<td>17/01/14</td>
</tr>
<tr>
<td></td>
<td>Letters out to Year 8 participants</td>
<td>31/01/14</td>
</tr>
<tr>
<td></td>
<td>Evening meeting to present research to concerned/interested parents</td>
<td>07/02/14</td>
</tr>
<tr>
<td></td>
<td>Develop programme to final prototype stage, including manual and feedback sheets, with sufficient materials for a class</td>
<td>14/02/14</td>
</tr>
<tr>
<td></td>
<td>Consent forms returned</td>
<td>14/02/14</td>
</tr>
<tr>
<td></td>
<td>Train tutor and teaching assistant(s) to deliver programme</td>
<td>14/02/14</td>
</tr>
<tr>
<td>Purpose</td>
<td>Main Activity</td>
<td>Completed by</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Data Collection</td>
<td>Group interview with 2 experts for feedback re theoretical development</td>
<td>08/11/13</td>
</tr>
<tr>
<td></td>
<td>Group interview with 2 experts for feedback re task development</td>
<td>06/12/13</td>
</tr>
<tr>
<td></td>
<td>Introduce first version prototype programme to mixed group of stakeholders (local expert, teacher and SENCo) and hold focus group on implementation issues</td>
<td>10/01/14</td>
</tr>
<tr>
<td></td>
<td>Gather baseline data for whole class</td>
<td>07/02/14</td>
</tr>
<tr>
<td></td>
<td>Lead first 6 sessions and observe 6 sessions, one per week</td>
<td>04/04/14</td>
</tr>
<tr>
<td></td>
<td>Interview programme administrators</td>
<td>25/04/14</td>
</tr>
<tr>
<td></td>
<td>Interview 6 participants and gather post-implementation data</td>
<td>25/04/14</td>
</tr>
<tr>
<td></td>
<td>Researcher’s reflective diary</td>
<td>Throughout</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>Transcribe interview re theoretical development</td>
<td>12/11/13</td>
</tr>
<tr>
<td></td>
<td>Identify recommended changes and check back with experts</td>
<td>15/11/13</td>
</tr>
<tr>
<td></td>
<td>Transcribe interview re task development</td>
<td>10/12/13</td>
</tr>
<tr>
<td></td>
<td>Identify recommended changes and check back with experts</td>
<td>13/12/13</td>
</tr>
<tr>
<td></td>
<td>Transcribe focus group on implementation issues</td>
<td>14/01/14</td>
</tr>
<tr>
<td></td>
<td>Full thematic analysis to identify recommended changes and check back with members</td>
<td>17/01/14</td>
</tr>
<tr>
<td></td>
<td>Analyse baseline data</td>
<td>14/02/14</td>
</tr>
<tr>
<td></td>
<td>Identify small research group members</td>
<td>04/04/13</td>
</tr>
<tr>
<td></td>
<td>Analyse observations</td>
<td>18/04/14</td>
</tr>
<tr>
<td></td>
<td>Transcribe interviews with programme administrators and participants</td>
<td>09/05/14</td>
</tr>
<tr>
<td></td>
<td>Full thematic analysis of programme administrators’ interviews, with inter-rater reliability checks</td>
<td>30/06/14</td>
</tr>
<tr>
<td></td>
<td>Full thematic analysis of interview with 6 participants, with inter-rater reliability checks</td>
<td>30/06/14</td>
</tr>
<tr>
<td></td>
<td>Content analysis of researcher’s diary</td>
<td>31/07/14</td>
</tr>
<tr>
<td>Purpose</td>
<td>Main Activity</td>
<td>Completed by</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Feedback</td>
<td>Create feedback sheets for Year 8 participants and school staff</td>
<td>21/07/14</td>
</tr>
<tr>
<td></td>
<td>Feedback meetings with participants and school staff</td>
<td>21/07/14</td>
</tr>
<tr>
<td>Write up</td>
<td>Literature Review (in addition to A2)</td>
<td>31/10/14</td>
</tr>
<tr>
<td></td>
<td>Methodology</td>
<td>21/11/14</td>
</tr>
<tr>
<td></td>
<td>Results</td>
<td>16/01/15</td>
</tr>
<tr>
<td></td>
<td>Discussion</td>
<td>21/02/15</td>
</tr>
<tr>
<td></td>
<td>Review time and appendices and formatting</td>
<td>01/05/15</td>
</tr>
</tbody>
</table>
### Table A3.2: Operational risk analysis

<table>
<thead>
<tr>
<th>Risk</th>
<th>Level</th>
<th>Measures to reduce risk</th>
<th>Contingency Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>SENCo decides research does not offer sufficient benefits to school</td>
<td>Low</td>
<td>- researcher leads initial sessions, trains administrators and supplies all materials, all of which school can keep - flexibility over session timings to minimise disruption</td>
<td>- contact other schools, either directly or through EPs</td>
</tr>
<tr>
<td>Headteacher refuses to host research</td>
<td>Low</td>
<td>- see above, plus optional meeting to present rationale and programme, highlighting potential benefits of an EF programme if successful</td>
<td>- offer further discussion to answer queries and worries - approach another school</td>
</tr>
<tr>
<td>No TA or Year 8 form tutor volunteers</td>
<td>Medium</td>
<td>- researcher leads initial sessions, and trains administrators - research activities do not take place in core lesson time - TA and form tutor are part of focus group looking at package before it is used in class</td>
<td>- offer discussion to answer queries and worries - approach another school</td>
</tr>
<tr>
<td>Year 8 participants and/or their parents refuse consent</td>
<td>Medium</td>
<td>- emphasise in background information that disruption to curriculum will be minimal, and the importance of the research and what students may gain. Information to include invitation to evening meeting to present rationale and programme</td>
<td>- ensure school has activities for form members not involved</td>
</tr>
<tr>
<td>Sessions are lost to other activities</td>
<td>Medium</td>
<td>- plan sessions around known interruptions</td>
<td>- if a full week of successive sessions is lost without unusual cause, identify 8 students to continue intervention as a separate small group</td>
</tr>
<tr>
<td>Sessions are lost to short term administrator absence</td>
<td>High</td>
<td>- intervention must be able to withstand such local disruption. - if either tutor or teaching assistant (TA) is absent, the sessions can continue.</td>
<td>- extend implementation period to make up lost time, modifying data collection dates accordingly</td>
</tr>
<tr>
<td>Sessions are lost to long term administrator absence</td>
<td>Low</td>
<td>- recruit and train more than one administrator - if either tutor or TA is absent, the sessions can continue.</td>
<td>- train an additional administrator to co-run the intervention</td>
</tr>
<tr>
<td>Year 8 participants withdraw from the study</td>
<td>Medium</td>
<td>- session activities to be fun, involve working in friendship pairs and require low literacy and numeracy levels; competition is restricted to self-improvement.</td>
<td>- identify 8 students to continue intervention as a separate small group</td>
</tr>
<tr>
<td>Experts and stakeholders decide not to participate</td>
<td>Low</td>
<td>- schedule interviews well in advance, offering flexibility over timing - aim to involve participants who have already expressed an interest - create a backup list of potential participants</td>
<td>- invite participants from the backup list</td>
</tr>
</tbody>
</table>
Appendix 3.3: Interview and focus group schedules

The following protocol will be followed for all interviews and the focus group:

1. Refreshments will be available on arrival. Consent forms to be completed if not already returned. Hard copy of relevant materials, including the question schedule, to be handed out, softcopies having been previously emailed where appropriate.
2. Introductions followed by brief description of how current interview/focus group fits into the research as a whole.
3. Individual or group discussion (40 minutes to an hour) to address the questions on the schedule. (Feedback interviews to be no more than 30 minutes.

The first expert group – addressing Research Question 1

Question 1: does the framework developed appear to combine relevant theoretical factors in a coherent way?

Question 2: does the framework propose coherent, plausible mechanisms for producing benefits?

Question 3: does the framework suggest logical ways to vary task difficulty and to order tasks within a programme?

Question 4: can the existing tasks (from first stage of research) be slotted into the framework such that gaps inviting further development become evident?

The second expert group – addressing Research Question 1

Question 1: have the tasks been developed in line with their assigned position within the theoretical framework?

Question 2: does the framework have an appropriate task coverage for an intervention targeting shift in young adolescents?

The mixed-perspective stakeholder focus group – addressing Research Question 2

Question 1: is the structure and management of the package obvious or at least easily accessible?

Question 2: does the rationale of the package become evident through use, or is extensive training needed?

Question 3: does the structure of the package appear to allow implementation within the current school environment?

Question 4: do materials appear accessible and attractive to Year 8 students?
The feedback interview with intervention administrator(s) – addressing Research Questions 2 and 3

Question 1: please can you describe an instance during the intervention where you felt it was running smoothly and achieving something positive. What factors contributed to this?

Question 2: please can you describe an instance where you felt the intervention did not run smoothly and/or was not achieving anything worthwhile. What factors contributed to this?

Question 3: what do you think students might have gained from taking part in this research? Have you noticed any changes in the way they interacted with the materials or managed in school more generally? Did these changes apply more to some students?

Question 4: what factors can you identify that might have interfered with running this intervention, to do with the intervention itself or classroom issues?

Question 5: having run the intervention, what would you change and why? (Have prompts available regarding design of materials, nature of activities and day-to-day management.)

The feedback interview with student participants – addressing research questions 2 and 3

Question 1: please can you describe a time during the research that you enjoyed and/or felt you were being challenged.

Question 2: how has the way you use the thinking skills materials changed during the trials?

Question 3: how have the activities changed the way you do other things? Which lessons do you think you have seen most changes in and what has changed?

Question 4: how has the research changed the way you feel about yourself and the way you approach your learning?

Question 5: please can you describe a time during the research that you didn't enjoy and/or when you weren't sure what you were doing. Can you suggest the reasons?

Question 6: thinking about the specific activities themselves and how they have been fitted into your school day, what would you change and why? (Have prompts available regarding design of materials, nature of activities and day-to-day management.)
Appendix 3.4: Prompts supplied in programme facilitator diaries

Please record briefly your thoughts to do with running the intervention. These can be about any aspect at all. You may find the following useful prompts:

- Have you been able to run the intervention sessions when planned?
- How have the students responded to the intervention?
- What factors have helped/hindered student self-management?
- What factors have helped/hindered student interest?
- What have you noticed about how the students approach the tasks?
- What factors have helped/hindered your running of the intervention, both to do with the intervention itself and wider issues?
- What mistakes have you noticed within the materials?
- What improvements would you suggest?
Appendix 3.5: Ethics forms submitted and approved and research approval details

Research risk and ethics assessment form

<table>
<thead>
<tr>
<th>RIA reference</th>
<th>Date received</th>
<th>Date approved</th>
</tr>
</thead>
</table>

RESEARCH RISK AND ETHICS ASSESSMENT
School of Education, University of Manchester

To be completed by QA administrator

SECTION A - SUMMARY OF RESEARCH PROPOSAL
This section should be completed by the person undertaking the research.

<table>
<thead>
<tr>
<th>A1. Name of Person/Student:</th>
<th>Susan Darby</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2. Student ID (quoted on library/swipe card):</td>
<td>20751360</td>
</tr>
<tr>
<td>A3. Email Address:</td>
<td><a href="mailto:susan_darby@hotmail.com">susan_darby@hotmail.com</a></td>
</tr>
<tr>
<td>A4. Name of Supervisor:</td>
<td>Dr Kath Tyldesley</td>
</tr>
<tr>
<td>A5. Supervisor email address &amp; contact phone no.:</td>
<td><a href="mailto:kathleen.tyldesley@manchester.ac.uk">kathleen.tyldesley@manchester.ac.uk</a> 0161 275 7282</td>
</tr>
<tr>
<td>A6. Programme (PhD, ProfDoc, MEd, PGCE, MSc, BA etc):</td>
<td>Doctorate in Educational and Child Psychology</td>
</tr>
<tr>
<td>A7. Year of Study</td>
<td>1</td>
</tr>
<tr>
<td>A8. Full/Part-time</td>
<td>Full-time</td>
</tr>
<tr>
<td>A9. Course Code</td>
<td>EDUC</td>
</tr>
<tr>
<td>A10. Title of Project:</td>
<td>Boosting the mental flexibility or shift capacity of young adolescents to benefit their self-regulation and performance in school: a feasibility study.</td>
</tr>
<tr>
<td>A11. Participant Recruitment Start Date:</td>
<td>On confirmation of ethical approval</td>
</tr>
<tr>
<td>A12. Submission Date:</td>
<td>30/07/13</td>
</tr>
<tr>
<td>A13. Proposed Fieldwork Start Date:</td>
<td>04/11/13 (Background theoretical work to start 03/09/13)</td>
</tr>
<tr>
<td>A14. Location(s) where the project will be carried out:</td>
<td>Interviews re programme development (with expert practitioners) at the University. Programme trials and feedback interviews/focus group in a secondary school within fieldwork Local Authority area.</td>
</tr>
<tr>
<td>A15. Student Signature:</td>
<td>Susan Darby 30/07/13</td>
</tr>
</tbody>
</table>
SECTION B – DESCRIPTION OF RESEARCH

This section should be completed by the person undertaking the research.

B1. Provide an outline description of the planned research (250 words max).

Executive Function (EF) comprises broad self-regulatory processing. It has received an increasing amount of attention as its importance in facilitating academic achievement in education and day-to-day self-regulation has become recognised (Röthlisberger & Neuenschwander, 2012). Evidence-based interventions for children are scarce (McCloskey, Perkins & Van Divner, 2009) and none have so far been identified as directly and exclusively targeting the underlying EF component known as switch or shift. Defined as the ability to shift between mental states, operations, or tasks (Miyake et al, 2000) this is seen to confer mental flexibility and is implicated in maths and reading skill (Yeniad, Malda, Mesman, Ijzendoorn, & Pieper, 2013). The aim of this study is to progress from recent feasibility research (Darby, 2013) that furnished background information regarding programme task characteristics and likely implementation issues, to develop a coherent intervention.

Associated research questions are:

1. How could a prototype shift intervention with sound theoretical underpinnings be developed for young adolescents?
   Envisaged outputs from addressing this question are one or more theoretical models and a battery of tasks that have an indicated order of presentation, but with some room for flexibility.

2. How might such a shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?
   Envisaged output is a prototype package endorsed by stakeholders.

3. To what extent could such a shift intervention package produce anticipated and/or useful benefits?
   Envisaged output is a tentative evaluation, based on a Year 8 class-based intervention with a focus on 6-8 pupils.
B2. The principal research methods and methodologies are (250 words max):

The research study is a mixed methods interpretive exploratory evaluation. Specific methods used to address the research questions are:

Question 1: two semi-structured group interviews with ‘experts’ who have EF research experience at postgraduate level, to ensure robustness of theoretical stages of programme development. Interviews will be audio-recorded, fully transcribed and subjected to content analysis and then member checking.

Question 2: a) a pre-implementation focus group comprising stakeholders from different professions, to discuss the first version prototype intervention package. Discussion will be audio-recorded, fully transcribed and subjected to thematic analysis and then inter-rater reliability and member checking.

b) post-implementation individual interviews with programme administrators and six student participants. These will be audio-recorded, fully transcribed and subjected to thematic analysis and then inter-rater reliability and member checking.

c) implementation observations, notes being analysed for content themes.

Question 3: concurrent mixed methods with a) a time series design (O₁O₂O₃O₄) within the intervention time frame.
b) a quantitative pre-experimental one group pre-test post-test design (O₁XO₂) examining changes in Shift skill.
c) post-implementation individual interviews, as above for research question 2.

The researcher will also keep a reflective diary and this will be subjected to a content analysis. Themes may feed into any of the research questions.

B3. Please indicate which of the following groups are expected to participate in this research:

- Children under 16, other than those in school, youth club, or other accredited organisations.
- Adults with learning difficulties, other than those in familiar, supportive environments.
- Adults who are unable to self-consent
- Adults with mental illness
- Those who could be considered to have a particularly dependent relationship with the researcher
- Prisoners
- Young Offenders
- Other vulnerable groups (please detail)

OR

- None of the above groups are involved in this study

B4. Number of expected research participants. 31

B5. The research will take place (tick all that apply):

- within the UK
- within the researcher’s home country if outside the UK
- wholly or partly outside the UK and not in the home country of the researcher*

* You must also complete a separate Fieldwork Risk Assessment form
SECTION C – RESEARCH RISK ASSESSMENT

The following sections should be completed by the person undertaking the research in discussion with their supervisor/tutor.

C.0 – Criteria for research classified as **HIGH RISK** – NRES

<table>
<thead>
<tr>
<th>Option</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️</td>
<td>The study involves primary research with adults who are unable to self consent</td>
</tr>
<tr>
<td>✔️</td>
<td>The study involves primary research with NHS patients</td>
</tr>
<tr>
<td>✔️</td>
<td>The study involves primary research with prisoners/young offenders</td>
</tr>
</tbody>
</table>

**Students** - If any of these options apply, you should complete an NRES application. See your supervisor for further guidance.

**Supervisors** – Forward this RREA form to ethics.education@manchester.ac.uk when you are satisfied that the project requires an IRAS application.

C.1 – Criteria for research classified as **HIGH RISK** (tick any that apply)

I/we confirm that this research:

<table>
<thead>
<tr>
<th>Option</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️</td>
<td>involves vulnerable or potentially vulnerable individuals or groups as indicated in B3</td>
</tr>
<tr>
<td>✔️</td>
<td>addresses themes or issues in respect of participant’s personal experience which may be of a sensitive nature (i.e. the research has the potential to create a degree of discomfort or anxiety amongst one or more participants)</td>
</tr>
<tr>
<td>✔️</td>
<td>cannot be completed without data collection or associated activities which place the researcher and/or participants at personal risk*</td>
</tr>
<tr>
<td>✔️</td>
<td>requires participant informed consent and/or withdrawal procedures which are not consistent with accepted practice</td>
</tr>
<tr>
<td>✔️</td>
<td>addresses an area where access to personal records (e.g. medical), in collaboration with an authorised person, is not possible</td>
</tr>
<tr>
<td>✔️</td>
<td>involves primary data collection on an area of public or social objection (e.g. terrorism, paedophilia)</td>
</tr>
<tr>
<td>✔️</td>
<td>makes use of video or other images captured by the researcher, and/or research study participants, where the researcher cannot guarantee controlled access to authorised viewing.</td>
</tr>
<tr>
<td>✔️</td>
<td>will involve direct contact with participants in countries on the Foreign and Commonwealth Office warning list *</td>
</tr>
<tr>
<td>✔️</td>
<td>involves face to face contact with research participants outside normal working hours¹ that may be seen as unsocial or inconvenient*</td>
</tr>
<tr>
<td>✔️</td>
<td>will take place wholly or partly without training or qualified supervision*</td>
</tr>
<tr>
<td>✔️</td>
<td>requires appropriate vaccinations which are unavailable*</td>
</tr>
<tr>
<td>✔️</td>
<td>will take place in locations where first aid and/or other medical support or facilities are not available within 30 minutes*</td>
</tr>
<tr>
<td>✔️</td>
<td>may involve the researcher operating machinery, electrical equipment, or workplace vehicles, or handling or working with animals at the research location(s), for which they are not qualified, and where a qualified operative or handler is not available to act as supervisor.*</td>
</tr>
</tbody>
</table>

¹ For example, in the UK, normal working hours are between 8am-6pm, Mon-Fri inclusive.
* IF YOU HAVE TICKED these HIGH risk criteria you must also complete a separate Fieldwork Risk Assessment form

IF YOU HAVE ONLY TICKED HIGH risk criteria NOT marked (*) you MUST complete the LOW Risk Fieldwork Declaration on page 9 of this form

<table>
<thead>
<tr>
<th>A. PGR research</th>
<th>B. PGT/ UG research not reviewing/evaluating professional roles or practice</th>
<th>C. PGT or UG research reviewing/ evaluating professional roles or practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>If ONE OR MORE of the HIGH risk criteria have been selected ethical approval must be sought from a UREC committee. The person undertaking the research and their supervisor should agree this risk assessment and submit:</td>
<td>If ONE OR MORE of the HIGH risk criteria have been selected ethical approval must be sought from a UREC committee. The supervisor and person undertaking the research should agree this risk assessment and submit:</td>
<td>If ONE OR MORE of the HIGH risk criteria have been selected ethical approval must be sought from the School of Education (SoE) Research Integrity Committee (RIC). The supervisor and student agree this risk assessment and submit:</td>
</tr>
<tr>
<td>- Completed RREA form</td>
<td>- Completed RREA form</td>
<td>- Completed RREA form</td>
</tr>
<tr>
<td>- Completed the UREC form.</td>
<td>- Completed the UREC form.</td>
<td>- Completed SoE Ethical Approval Application</td>
</tr>
<tr>
<td>- Completed Fieldwork</td>
<td>- Completed Fieldwork</td>
<td>-</td>
</tr>
</tbody>
</table>

The documents listed above should be submitted to:

A. Mrs. Debbie Kubiena, Room B3.10 along with your PhD Research Plan for consideration at the PhD/Prof Doctorate Review Panel.

B. The Quality Assurance Administrator via Ethics.Education@manchester.ac.uk by your supervisor. In doing so, supervisors confirm that they have agreed the assessed risk level and that the documents are complete and correct. The QA Administrator will arrange authorisation for your documents to be submitted to UREC.

C. The Quality Assurance Administrator via Ethics.Education@manchester.ac.uk by your supervisor. In doing so, supervisors confirm that they have agreed the assessed risk level and that the documents are complete and correct. The QA Administrator will forward your completed documents to a member of the SoE RIC committee for approval.

If no HIGH risk items are ticked supervisors and students should continue to section C.2 on the next page ➤
C.2 – Criteria for research classified as MEDIUM RISK (tick any that apply)

I/we confirm that this research:

- [X] is primary research involving children or other vulnerable groups which involves direct contact with participants.
- study is on a subject that a reasonable person would agree addresses issues of legitimate interest, where there is a possibility that the topic may result in distress or upset in rare instances.
- is primary research which involves substantial direct contact with adults in non-professional roles.
- is primary research which focuses on data collection from professionals responding to questions outside of their professional concerns.
- is primary research involving data collection from participants outside of the EU or the researcher’s home country via direct telephone, video, or other linked communications.
- is practice review/evaluation involving topics of a sensitive nature which are not personal to the participants.
- involves visits to site(s) where a specific risk to participants and/or the researcher has been identified, and the researcher may not be closely supervised throughout.
- requires specific training and this is scheduled to be completed before fieldwork starts, or, training will not be undertaken but the research will be closely supervised by an academic advisor with appropriate qualifications and skills.
- requires vaccinations which have been received, or are scheduled to be received in a timely fashion.
- requires face to face contact with research participants partly outside normal working hours that may be seen as inconvenient.
- takes place in, or involves transport to and from, locations where the researcher’s lack of familiarity may put them at personal risk.
- may require the operation of machinery, electrical equipment, or workplace vehicles, or handling or working with animals at the research location(s), for which they are not qualified, but such operation or handling will be undertaken under close supervision from a qualified operative or handler.

* IF YOU HAVE TICKED these MEDIUM risk criteria you must also complete a separate Fieldwork Risk Assessment form

* IF YOU HAVE ONLY TICKED MEDIUM risk criteria NOT marked (*) you MUST also complete the LOW Fieldwork Risk Declaration on page 9 of this form

---

2 This does not include research in locations where children are present if they are not the focus of the research.

3 For example in focus group or one to one interview in private locations, and not ‘market research’ which is characterised by brief interaction with randomly selected individuals in public locations.

4 In the UK normal working hours are between 8am-6pm, Mon-Fri inclusive.
If ONE OR MORE of the MEDIUM risk criteria have been selected, ethical approval must be sought from the School of Education (SoE) Research Integrity Committee (RIC) and so you should complete the SoE Ethical Approval Application form (available on the School of Education Ethics Intranet).

The supervisor and student should agree this RREA assessment and submit:

- Completed RREA form
- Completed School of Education Ethical Approval Application form
- Completed Fieldwork Risk Assessment form where indicated
- Supporting documents.

NB: ‘Supporting documents’ include recruitment adverts/emails, draft questionnaires / interview topic guides, information sheets and consent forms.

Document should be submitted for review as indicated below:

PGR Thesis - Mrs. Debbie Kubiena, Room B3.10 along with your PhD Research Plan for consideration at the PhD/Prof Doctorate Review Panel.

A. All other cases - to the Quality Assurance Administrator via Ethics.Education@manchester.ac.uk by your supervisor. In doing so, supervisors confirm that they have agreed the assessed risk level and that the documents are complete and correct. The QA Administrator will forward your completed documents to a member of the SoE RIC committee for approval.

If none of the HIGH or MEDIUM risk criteria have been ticked, supervisors and students should continue to section C3 on the next page

C3 – Criteria for research classified as LOW RISK

C 3.1 Research not involving human participants

I/we confirm that this research (tick as appropriate):

- is not of high nor medium risk to the researcher, in accordance with the criteria provided in sections C.1 and C.2 respectively.
- is Secondary research (i.e. it will use material that has already been published or is in the public domain).
- is Secondary data analysis (i.e. it will involve data from an established data archive)

If you have ticked one of the options in C3.1 above, and C3.2 does not apply, you should now complete section C3.3

---

This document and guidance for completion can downloaded from http://www.education.manchester.ac.uk/intranet/ethics
C3.2 Research involving human participants

I/we confirm that this research (tick as appropriate):

☐ is not of high nor medium risk to the researcher, or participants, in accordance with the criteria provided in sections C.0, C.1 and C.2 respectively.

A reasonable person would agree that the study addresses issues of legitimate interest without being in any way likely to inflame opinion or cause distress.

☐ is Practice review (i.e. the research involves data collection from participants on issues relating to the researcher’s professional role, in a setting where the researcher is employed or on a professional placement).

☐ is Practice evaluation (i.e. the research involves data collection on a student’s professional role, in a setting where the researcher is employed or on a professional placement. The data collected will be used for comparison against national or other targets or standards).

☐ is Primary research on professional practice with participants in professional roles conducted in their work setting.

☐ is Market research (i.e. the research may involve data collection from the general public approached or observed in public locations for the purposes of market investigation).

☐ is Primary research using a questionnaire completed and returned by participants with no direct contact with the researcher.

☐ is part of a research methods course and participant groups are limited to peers, colleagues, family members and friends.

C 3.3 Research context

I/we confirm (tick as appropriate):

☐ the location(s) of the research are not listed on the Foreign and Commonwealth Office warning lists.

☐ the researcher is not in a position to coerce potential participants/secondary data owners

Primary or practice research involves no vulnerable group (as indicated in question B3).

Primary or practice research will be conducted in a public space or building (e.g. the high street, the University campus, a school building, etc)

---

6 A reasonable person would agree that the study includes no issues of public or private objection, or of a sensitive nature.

### D. LOW Risk Fieldwork Declaration

*Students not directed to complete the separate Fieldwork Risk Assessment in Section C should tick the items in D.1 or D.2 to confirm the LOW risk nature of their fieldwork visits. Then sign the Declaration in D.3*

**D.1 Fieldwork visit items** *(If you will *not* make any fieldwork visits, tick the alternative items in D.2 below.)*

I/we confirm:

- [X] the researcher will not travel outside the UK or their home nation.
- [X] the fieldwork does not require overnight stays in hotels or other types of public temporary accommodation.
- [X] public and private travel to and from the research location(s) are familiar to the researcher and offer no discernable risk.
- [X] the researcher will not travel through, or work in research locations which may have unlit areas, derelict areas, cliffs, or local endemic diseases
- [X] the researcher will carry only necessary personal items when travelling to, and within, research locations.
- [X] no specific vaccinations are required to undertake this research
- [X] first aid provision and a trained first aider are available where appropriate
- [X] the researcher will only operate machinery, electrical equipment, or workplace vehicles, or handle or work with animals at the research location(s) if they are qualified to do so
- [X] the fieldwork will be carried out within normal working hours\(^8\) at a time convenient to participants.
- [X] the researcher will not give out personal telephone information to participants, or owners of secondary data resources, in relation to the research project
- [X] the researcher is fully aware of and sensitive to cultural and religious practices of participant groups, and will act accordingly.
- [X] primary or practice research will not involve fieldwork visits to private homes.
- [X] the researcher will provide a regularly updated fieldwork visit schedule to a nominated University contact.
- [X] the researcher will carry a School of Education Emergency Contact Information Card during all fieldwork visits.

*If you are unable to tick all items above, you must complete a separate Fieldwork Risk Assessment form.*

**D.2 No Fieldwork visits items**

I/we confirm

- [ ] this research does not involve fieldwork visits of any kind
- [ ] the researcher will not give out personal telephone information to participants, or owners of secondary data resources, in relation to the research project

---

\(^8\) For example, in the UK normal working hours are between 8am and 6pm Mon-Fri inclusive.
PGR Panel Students

PGR Panel Students

If ONE OR MORE of the LOW risk criteria above have been selected, ethical approval must be sought from the School of Education Research Integrity Committee. The supervisor and student should agree this research risk assessment and submit:

- Completed RREA form
- Completed the School of Education Ethical Approval Application form
- Completed Fieldwork Risk Assessment form where indicated
- Supporting documents

NB: ‘Supporting documents’ include recruitment adverts/emails, draft questionnaires / interview topic guides, information sheets and consent forms.

Documents should be submitted to:

Mrs. Debbie Kubiena, Room B3.10 along with your PhD Research Plan for consideration at the PhD/Prof Doctorate Review Panel.

⇒ **UG and PGT research that involves only low risk criteria go to Section E.1 page 12**
### E. 1 Research ethics criteria

I/we confirm (tick as appropriate):

#### Codes of Practice

- I/we have read and understood the School of Education Ethical Practice and Policy Guidelines
- the researcher will abide by the School of Education’s Ethical Protocol detailed therein
- the researcher is aware of and will abide by any organisation’s codes of conduct relevant to this research

#### Researcher skills/checks

- all necessary training procedures for this research have been completed
- all appropriate permissions have been obtained to use any database or resource to be analysed in Secondary research
- all relevant enhanced CRB checks have been completed
- written permission to be on the site to conduct primary research has been received

#### Rights of participants

- participant information sheets (PIS), consent forms, questionnaires, and all other documentation relevant to this research have been discussed with supervisor/tutor named in A.5
- PIS and consent forms have been confirmed by the supervisor named in A.5, as covering required headings illustrated in the School of Education Participant Information and consent templates, AND as accessible to proposed participant groups.
- the researcher understands the Data Protection Act and the University Data Protection Policy and all data will be handled confidentially and securely, including storage on encrypted devices.

#### Research Integrity

- no data will be collected before approval of the study by the supervisor/tutor
- the student researcher will immediately report any issues arising during the course of the study that conflict with the School of Education protocol, to the supervisor who has signed the ethics approval and suspend data collection pending advice from that supervisor/tutor
- the researcher will report any proposed deviation from the research specification outlined in this assessment to the supervisor/tutor to update the current assessment or clarify any need for further approvals BEFORE such changes are made

#### Research output

- the only publication/output from this research will be the assignment or dissertation unless consent has been obtained from participants for further dissemination
E.2 Supervisor confirmation that research matches LOW risk criteria above.

When satisfied that the assessment is correct, supervisors should complete this section.

For ‘low risk’ research approval relevant items in bold must be ticked and one or more of the specific research criteria as appropriate.

The supervisor confirms:

- The submission has been discussed and agreed with the person(s) undertaking the research.
- The student has had appropriate training and has the skills to undertake this study, or has qualified supervision in place.
- The research activities outlined in the proposal involve no substantive risks to the student researcher or potential participants.

and one or more of the following as appropriate:

- Primary or Practice research will not address issues of public or social objection or of a sensitive nature.
- Information giving and consent taking processes follow School of Education guidance.
- Where fieldwork visits do not correspond to all items in the LOW Risk Fieldwork Declaration, a separate Fieldwork Risk Assessment form has been completed and approved.
- Secondary research assignment/project has appropriate resource or database access permissions.
- They will act as custodian for data used for any study that results in a publication (Masters dissertation or otherwise) and will arrange for archiving of data within the School for a minimum period of 5 years.

Supervisor’s signature: [Signature]

Date: 30.7.13

IF all relevant items in BOLD are confirmed and in addition all specific criteria relating to primary, practice or secondary research are confirmed as appropriate, the supervisor should submit:

- Completed RREA form
- Completed Fieldwork Risk Assessment form where indicated
- Student research proposal, or equivalent, on which the assessment is based
- Supporting documents

Documents should be submitted electronically for archiving and audit purposes, to the Quality Assurance Administrator via Ethics.Education@manchester.ac.uk by the supervisor. In doing so, supervisors confirm that they have agreed the assessed risk level and that the documents are complete and correct. The QA administrator will acknowledge receipt of the

---

10 ‘Supporting documents’ include recruitment adverts/emails, draft questionnaires/interview topic guides, information sheets and consent forms
documents and provide formal confirmation of ethical approval via email to both student and supervisor. Copies of all documents should be retained by the supervisor.

E.3 Amendments to proposed research design for LOW risk research

Any minor amendment to low risk approved research submissions should be recorded and signed-off by the supervisor as necessary below. Substantial changes to research will require a reassessment and revised ethical approvals. A revised copy of the RREA showing the approved amendments, and any amended supporting documents, should be forwarded electronically to The QA administrator via ethics.education@manchester.ac.uk. The QA administrator will provide formal acknowledgement of approval of the change by email. A copy should be retained by the supervisor.

To be completed if/when applicable:

<table>
<thead>
<tr>
<th>Minor amendment to assessed research agreed (1):</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Details of amendment</strong></td>
</tr>
<tr>
<td>This section will record any applications made during the life time of the Project regarding minor changes from what was approved.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supervisor’s signature:</th>
<th>Date:</th>
</tr>
</thead>
</table>

School of Education ethical approval application form

---

11 Minor amendments are those that do not alter the character of the research or the participant groups

12 Minor deviations from previously approved research submissions are defined as those which neither change the nature of the study nor deviate from any participatory research groups previously identified. Supervisors should contact a member of the SoE Research Integrity Committee for advice if in doubt.
School of Education
Ethical Approval Application Form

The ethical approval application form must contain answers to all the questions indicated in the boxes below, if they do not apply please state why.

SECTION 1 Student Details /Identification of the person responsible for the research

<table>
<thead>
<tr>
<th>Name of Student:</th>
<th>Susan Darby</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student ID (quoted on library/ swipe card):</td>
<td>20751360</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:susan_darby@hotmail.com">susan_darby@hotmail.com</a></td>
</tr>
<tr>
<td>Name of Supervisor:</td>
<td>Dr Kath Tyldesley</td>
</tr>
<tr>
<td>Programme (PhD, Prof Doc, MEd, PGCE, MSc, BA etc):</td>
<td>Doctorate in Educational and Child Psychology</td>
</tr>
<tr>
<td>Year of Study</td>
<td>1</td>
</tr>
<tr>
<td>Full/Part-time</td>
<td>Full time</td>
</tr>
<tr>
<td>Title of Project:</td>
<td>Boosting the mental flexibility or shift capacity of young adolescents to benefit their self-regulation and performance in school: a feasibility study.</td>
</tr>
<tr>
<td>Location(s) where the project will be carried out:</td>
<td>Interviews re programme development (with expert practitioners) at the University. Programme trials and feedback interviews/focus group in a secondary school within fieldwork Local Authority area.</td>
</tr>
<tr>
<td>No risk, or acceptable levels of risk (measures documented)</td>
<td>Medium</td>
</tr>
<tr>
<td>Student Signature:</td>
<td></td>
</tr>
<tr>
<td>Supervisor Signature:</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td>30.7.13</td>
</tr>
</tbody>
</table>

** Supervisor signature confirms that the student has the relevant experience, knowledge and skills to carry out the study in an appropriate manner

SECTION 2 PROJECT DETAILS (Please expand boxes to fit answers)

1. **Aims and Objectives of the Project**
A. Provide a statement of your research aims and objectives including research questions.
This study aims to produce a coherent prototype intervention targeting young adolescents’ mental flexibility, working on the Executive Function (EF) component Shift and through social mediation and feedback. The research questions are:

1. How could a prototype shift intervention with sound theoretical underpinnings be developed for young adolescents?
2. How might such a shift intervention be packaged so that it is suitable for implementation in a mainstream secondary school?
3. To what extent could such a shift intervention package produce anticipated and/or useful benefits?

B. What is the justification for the research? (why is it an area of importance/has any similar research been done)
Executive Function has received an increasing amount of attention as its importance in facilitating academic achievement in education and day-to-day self-regulation has become recognised (Röthlisberger & Neuenschwander, 2012). Evidence-based interventions for children are scarce (McCloskey, Perkins & Van Divner, 2009) and none have so far been identified as directly and exclusively targeting the underlying EF component known as switch or shift. Defined as the ability to shift between mental states, operations, or tasks (Miyake et al, 2000) this can be seen to confer mental flexibility and has been implicated in maths and reading skill (Yeniad, Malda, Mesman, Ijzendoorn, & Pieper, 2013). Adolescents’ shift skills are still developing (Dumonthell, Hassan, Gilbert, & Blakemore, 2010) and laboratory-based work appears to indicate they are amenable to intervention (Diamond, 2012). The growing evidence for day-to-day negative implications of weaker EF skills provides a strong imperative to investigate the possibility of boosting EF, including the component shift and this study aims to move research on by developing an intervention for adolescents for use in a typical school environment.

C. What are the main ethical issues and what steps will be taken to address them?

1. That students feel peer pressure resulting from the recruitment of a whole class. In this scenario it may be harder for participants to feel that they are volunteers and can withdraw from the research.

   The right to withhold consent initially and to withdraw at any time will be made clear in written information provided and in an information evening in school led by the researcher.

2. That anxiety is generated in students by the gathering of Shift measures in a 1-to-1 situation.

   The researcher will emphasize that it is the intervention rather than the student who is being tested. The students won’t know how they scored as individuals, but will later receive feedback regarding the intervention as a whole. The form tutor and TA involved with the class/intervention will be available on a daily basis to monitor for induced anxiety, to dissipate it through usual school pastoral care and to contact the researcher if necessary to request additional debriefing time.

3. That anxiety is generated in students by the feedback inherent in the intervention.

   The order of the intervention activities is expected to involve some initial sessions for getting used to the kinds of tasks included and to the idea that unexpected mistakes are part of the territory and the interest. At this point, feedback is in the form of students and their work partners noticing mistakes and then discussing them and feeding back to the class. It is anticipated that when a timing element is introduced (to be recorded in a progress booklet), students will be comfortable with the activities and the situation. (This was the case in previous research.) The form tutor and TA involved with the class/intervention will be available on a daily basis to monitor for induced anxiety, to dissipate it through usual school pastoral care and to contact the researcher if necessary to request additional debriefing time.
2. **Methodology**

A. Please outline the **design and methodology** of the project, including the methods of data collection and the methods of data analysis and the theoretical framework that informs it.

The research study is a mixed methods interpretive exploratory evaluation, conducted from the perspective of Critical Realism.

The specific methods used to address each research question are as follows:

**Question 1:** two semi-structured group interviews with ‘experts’ who have EF research experience at postgraduate level, to ensure robustness of theoretical stages of programme development. Interviews will be audio-recorded, fully transcribed and subjected to content analysis and then member checking.
Question 2: a) a pre-implementation focus group comprising stakeholders from different professions, to discuss the first version prototype intervention package. The discussion will be audio-recorded, fully transcribed and subjected to thematic analysis and then inter-rater reliability and member checking.
b) post-implementation individual interviews with programme administrators and six student participants. These will be audio-recorded, fully transcribed and subjected to thematic analysis and then inter-rater reliability and member checking.
c) implementation observations, notes being analysed for content themes.

Question 3: concurrent mixed methods with a) a time series design \((O_1, O_2, O_3, O_4)\) within the intervention time frame, measures comprising students’ numeric written entries in their progress booklets.
b) a quantitative pre-experimental one group pre-test post-test design \((O_1, XO_2)\) examining changes in Shift skill; pre-test measures will be for the whole class and post-test for a small student group, identified through examination of data from (a).
c) post-implementation individual interviews, as above for research question 2; particularly those with students will go on to explore tentative/formative suggestions regarding direct far transfer effects, including specific curriculum benefits.
The researcher and involved school staff will keep reflective diaries throughout and these are likely to feed into answers for all research questions. They will be subjected to a content analysis.

B. A description of the research procedures/activities as they affect the study participant and any other parties involved.

Research question 1:
The parties involved in the group interviews will be the expert participants and the researcher as facilitator. The interviews will be held at times and locations convenient to the experts. Information will be sent by email before each interview. The discussion will be audio-recorded and analysed as above, as per experts’ written consent, see earlier appendix.

Research question 2:
The parties involved with the focus group will be the researcher as facilitator and the participants who are expected to include one or more experts, the tutor and TA who will manage the intervention and the school SENCo. The focus group will be held in the host school at a time convenient to the stakeholders. Information will be sent by email before each interview. The discussion will be audio-recorded and analysed as above, as per participants’ written consent, see earlier appendix.
The parties involved in the observations will be the researcher as observer and the tutor, TA and students as the observed. Notes made will be anonymous and used to inform understanding of local fidelity, adaptation, barriers and drivers, as well as how student engagement/progress differs and why.

The parties involved with the feedback interviews will be the researcher who will lead the discussion and the individual interviewees: tutor, TA(s) and six students. The interviews will be held in school at times convenient to the interviewees. The discussion will be audio-recorded and analysed as above, as per interviewees’ written consent.

Research question 3:
The parties involved in the gathering of performance data will be:
- for the initial Shift performance data – the researcher to administer assessments 1-to-1, the students to take them and the tutor/SENCo to help coordinate time slots.
- for the task feedback data – each student will complete their own simple table of data regarding time taken and number of errors made on a benchmark task, with their partner helping to collect this information.
- for the interviews - involvement is as for research question 2, as they are the same interviews. Students’ interviews will additionally involve taking a follow up Shift measure.
C. Please state your **experience** in conducting the research procedures/ activities and provide supporting evidence.

As a maths teacher, the researcher has around nine years of experience developing and using materials suitable for use with secondary aged children and young people. She has also regularly asked students for feedback regarding lessons. In addition she was a teacher and then researcher (over a total period of 18 months) in a project co-ordinated by MMU looking at the potential benefits of Realistic Mathematics Education*.

The researcher also has experience of using semi-structured interviews with adults. For example product evaluation for RNIB (four years), maternity service evaluation for Salford and Trafford Health Authority (6 months) and a teleworking pilot evaluated at The Cooperative Bank for Masters’ thesis (6 months).

As an assistant psychologist, the researcher has supervised experience of using the BRIEF questionnaire and a number of standardised tests.

More recently the researcher has been trained to use assessments similar to those that measure EF. She has also completed a small piece of research leading up to this study, that involved using group interviews and trialling some initial ideas for shift activities with a group of six Year 7 students.


**Attach copies of any draft instrument / interview guide / screen prints, and so on.**
See earlier appendices.
### 3. Participants

A. Give the number of participants; sex; age group and location

The participants have not yet been identified.

**EF experts:** 3 or 4, male or female adults, two group interviews at the University of Manchester and one focus group in a mainstream secondary school in researcher’s Local Authority.

**School staff:** 2 TAs and 1 form tutors, male or female adults, one focus group and a six week intervention with a Year 8 class in a mainstream secondary school in researcher’s Local Authority.

**Students:** a class of around 25 Year 8 students (so 12 - 13 years old) in a mainstream secondary school in researcher’s Local Authority.

B. Will your project include participants from any of the following groups? (Tick as appropriate)

- [ ] X YES Children under 16
- [ ] Adults with learning difficulties
- [ ] Adults with mental illness
- [ ] Those who could be considered to have a particularly dependent relationship with the researcher
- [ ] Prisoners
- [ ] Young Offenders
- [ ] Other vulnerable groups (please detail)

C. If your project includes vulnerable populations please explain why it is necessary to include them in your study, including measures you will take to avoid coercion.

It is important to involve participants of this age in research on EF because of the potential benefits in the school environment and beyond. More specifically an evaluation of intervention materials should include the views of the people for whom they are intended and measures of any benefits they derive, or otherwise. Participation will only be by informed consent and withdrawal will be possible at any point. This has been discussed in Section 1C above.

### 4. Recruitment – see earlier appendices for information provided

A. How will potential participants be:

i) Identified

ii) Approached and Recruited

**EF experts:**

i) through local knowledge within the University, of people in the Manchester area known to have a research interest in EF at post-graduate level.

ii) will be contacted by e-mail and/or telephone and sent background information with a consent form, see earlier appendix.

**School staff:**

i) the SENCo in the host school will identify all TAs and Year 8 form tutors.

ii) these school staff will be contacted by the SENCo, through announcements and discussions in staff meetings. The verbal invitations will be followed up with written background information supplied by the researcher through the SENCo, see earlier appendix. (TAs and Year 8 form tutors are being invited to co-run the programme or host the pilot intervention in their class respectively.) Expressions of interest will be followed up by a meeting with the researcher and the SENCo to identify a suitable class, and ensure its teacher (form tutor) and/or one or more teaching assistants feel able to manage the intervention.

**Students:**

i) The participants will be identified as a result of their form tutor volunteering to trial the prototype intervention.
ii) The research will be introduced to them by the researcher or their form tutor and they will be given a written invitation with a consent form, see earlier appendix. The students will have two weeks to return the consent form; in the intervening time there will be an information evening open to pupils and their parents/carers to find out more about the research before making a decision about participation. Towards the end of the intervention, eight students will be approached by their tutor or the researcher to volunteer to give feedback in an interview; it is hoped that six will volunteer. This will be covered by the initial consent form.

B. How will your recruitment policy avoid putting any overt or covert pressure on the individual to consent?

**EF experts:** only those with a known research interest will be approached, starting with those who have already expressed an interest in being involved.

**School staff:** participation is clearly indicated to be on a voluntary basis. The meeting with the researcher will have the functions of ensuring that potential participants know exactly what would be expected of them and that they have not been coerced into participating. The stakeholder focus group will be another opportunity to ascertain that school staff are not consenting under pressure.

**Student participants:** as indicated earlier, it is a concern that students may feel pressure resulting from the recruitment of a whole class, especially if their tutor is gushing with enthusiasm. However, having 2 weeks to consider should allow time to discuss concerns with parents/carers and to attend the information evening in school led by the researcher. The written information provided will make it clear that consent can be withheld and that withdrawal is acceptable at any time; it will also contain a University email address for the researcher as another avenue to address concerns.

C. How long will the participant have to decide whether to take part in the study?

**EF experts:** 1 week from receipt of an email. They can choose to be part of the 2 group interviews, the stakeholder focus group, or both.

**School staff:** from initial contact by the SENCo until the stakeholder focus group school staff will have about 2½ months to decide whether or not to join the research. However, a reasonably firm commitment would ideally be achieved within about 2 weeks of initial contact and by the end of the first meeting with the researcher.

**Student participants:** 2 weeks from being introduced to the research by their form tutor or the researcher.

D. State any payment or any other incentive that is being made to any study participant. Specify and state the level of payment to be made and/or the source of the funds/gift/free service to be used and the justification for it.

**N/A**

5. **Risk and Safeguards**

Please outline any adverse effects or risks for participants

A. What is the potential for adverse effects of a physical nature; risks or hazards, pain, discomfort, distress, or inconvenience, to participants?

**EF experts:** inconvenience is the most likely issue – around fitting the research into usual work commitments – with no reimbursement for time or travel costs.

**School staff:**

i) stress and anxiety could be induced by form time becoming more pressured because of having to fit in intervention activities alongside school administration. (See Section 2, Part 1, C6.)

ii) stress and anxiety could be induced by the intervention not running smoothly, because staff are not sufficiently familiar with it, the package contains inherent difficulties or because students do not respond to it as expected. (See Section 2, Part 1, C7 and 8.)

**Student participants:**

i) by having a more structured form time, pupils may feel they are missing out on chatting time with friends.
ii) distress and anxiety may be induced by the pressure to participate and by feelings of exposure particularly if students find the tasks hard. (See Section 2, Part 1, C1 – 5.)

B. Will any topics discussed (questionnaire, group discussion or individual interview) be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures requiring action could take place during the project? It is possible that the participants will offer examples of difficult situations, but this would be voluntary, and it is not a planned part of the sessions and so should not be more likely than in any other class time.

C. What is the potential for adverse effects, risks or hazards, pain, discomfort, distress, or inconvenience, of a physical or psychological nature to you as the researcher?
Adverse effects are most likely to be:
i) heightened stress levels due to research having to be fitted into fieldwork placement with little protected time, especially if school staff become reluctant to lead the intervention.
ii) feelings of failure and disappointment if at any stage it becomes clear that the intervention is not viable and should be shelved.
iii) stress due to research needing to be down-sized if at any stage it becomes clear that the intervention is not viable in a whole class setting.
iv) stress and guilt if school staff/students become stressed and/or anxious because of the intervention.

D. What precautions have been taken to minimise or mitigate the risks identified above in A, B, C?
A: **EF experts**: the most likely participants have already expressed an interest and have the flexibility to attend if reasonable notice is given. Otherwise, dates and venues would be set to accommodate participants so far as possible.

**School staff:**
i) It is anticipated that the two administrative roles (school eg register and intervention) will be jointly managed by the form tutor and a TA, so that both can proceed in parallel.
ii) Plans include the researcher visiting each week to pick up on difficulties and sorting them immediately so far as is possible. Staff will have received training before the intervention starts and will be supported as much as they want initially. There is a contingency plan of removing a small group and staff will be aware of this.

**Student participants:**
i) The intervention will allow working in friendship pairs. Other social opportunities such as break times will not be affected.
ii) The objectives of the research will be made clear on a number of occasions, ground rules will be established at the beginning and staff will be available for debriefing if necessary. (See Section 2, Part 1, C1-5).

B: The first session will be used to develop ground rules and to remind students that they can approach the tutor, TA or the researcher if any issues that arise are of concern to them.

C: i) This issue has already been raised with the Principal Educational Psychologist within researcher’s Local Authority and discussion has started to resolve it.
ii) Having previously been a teacher, the researcher has experience of interventions, both imposed and self-initiated, that are later shelved. To “lose” the research would be difficult, but as it is an evaluation this option has to be a possibility to be contemplated; hopefully supervision would ease acceptance of this!
iii) There is room in the timescales for data collection re research question 3 to slide by about half a term, if circumstances require this.

iv) Communications to date with school staff have been frank in nature; if this relationship style is maintained through offering multiple opportunities to raise and work through concerns, then hopefully staff will raise issues quickly and these will be resolved/contained in a timely way.

6. Consent

A. Detail how informed consent/ assent will be obtained.

**EF experts:** potential participants will be contacted by email or telephone. Most are likely to have been involved in an earlier stage of the research and so to have experience of the kind of group interview or focus group they are being asked to attend. They will be sent background information with a consent form to sign and return, see earlier appendix.

**School staff:** staff who are interested in participating in the research will be invited to a meeting with the SENCo and the researcher. Here the researcher will expand on the written information already given out, with the aim of insuring that staff know exactly what is being asked of them. Samples of tasks used previously will be presented to give a flavour of how sessions might run. Staff who are identified as likely participants will also then be invited to the stakeholder focus group where they will see the first version prototype package and later on to training by the researcher for the version to be used in school. Staff will not be asked to sign a consent form regarding the intervention until they have attended the training.

**Student participants:** through the process of recruitment into the study and being part of the focus group, it is hoped that the form tutor and TAs will be sufficiently familiar with the research to be able to give a realistic introduction to the Year 8 class. Nevertheless, if they prefer, the researcher will support this. Written information with a consent form will be given out, see earlier appendix. Further copies can be sent in the post if necessary.

Students will have two weeks to consider whether or not to take part in the research. During this time they will be able to consult parents/carers, their tutor and the researcher. A university email address for the researcher will be included in the information and issues can also be discussed at the proposed information evening.

During any session, participants will be able to discuss any concerns directly with the tutor or TA. The ongoing option of leaving the programme will be specifically discussed during the initial session.

B. If the participants are to be recruited from a vulnerable groups (3B) give details of the extra steps taken to assure their protection.

Debriefing will be available through the tutor, the TA and the researcher, as well as the school pastoral system as a whole.

The tutor and TA will watch out for any difficulties pairs of students have in working together, as they would in any lesson, and make partner changes as necessary and/or offer the opportunity to leave the research.

**Attach draft Information Sheets & Consent Forms for each participant group.**

See earlier appendix.

7. **Data Protection and confidentiality**

A. Will the pilot study use any of the following activities at any stage?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>YES Use of personal addresses, postcodes, faxes, e-mails or telephone numbers.</td>
</tr>
</tbody>
</table>

**Experts and school staff:** email and telephone will be used to make arrangements.
Anonymised themes for member checking will be sent by email. **Students:** personal addresses may be used by the SENCo or form tutor if students request consent form to be sent to home address.

<table>
<thead>
<tr>
<th>X YES</th>
<th>Publication of direct quotations from respondents – anonymous quotes from feedback interviews and possibly from research diaries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Publication of data that might allow identification of individuals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X YES</th>
<th>Use of audio/visual recording devices – audio-recording of stakeholder focus group (to include school staff) and of feedback interviews with school staff and student participants.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Storage of personal data on any of the following: [ Manual files ] [ Laptop computers ] [ Home or other personal computers ] [ University computers ] [ Private company computers ]</td>
</tr>
</tbody>
</table>

B. Please provide details on the measures you will employ to comply with the Data Protection Act and the University Data Protection Policy?

Hardcopy files will be stored securely in a locked cupboard/room. When taken out they will not be left unattended. They will be stored and destroyed in accordance with local procedures and timeframes – see C and G.

Consent for participation will include consent to gather relevant personal data which will only be used for the research project. It will be anonymised in any publications, as will any references to school staff, the school and the Local Authority.

C. What measures have been put in place to ensure confidentiality of personal data? Give details of whether any encryption or other anonymisation procedures have been used and at what stage?

All data will be anonymised at the point of entry into any form of electronic storage. In addition, data will be stored only on an encrypted data stick in files with passwords. Apart from consent forms, hardcopy information will be stored anonymously using coding. This will apply to measures record sheets/booklets that need to be linked over time for repeated measures. The coding information linking sheets/booklets to individuals will be kept separately on an encrypted data stick in a safe.

D. Where will the analysis of the data from the study take place and by whom will it be undertaken?

The researcher will analyse the data in a dedicated and private office at home, where data can also be stored securely.

E. Who will have control of and act as the custodian for the data generated by the study?

The researcher’s university supervisor Dr Kath Tyldesley.

F. Who will have access to the data generated by the study?

The researcher will have access to the full data set. The research and fieldwork supervisors will have access to anonymised data. School staff, parents and research participants will have access to the anonymised debriefing reports to be produced, that will summarise the research findings.

G. For how long will data from the study be stored?

The personal data from this piece of research will be destroyed five years after the research is completed, by deletion or shredding, as appropriate.

### 8) Reporting Arrangements

A. Please confirm that any adverse event will be reported to the Committee

**YES**

B. How is it intended the results of the study will be reported and disseminated?

*(Tick as appropriate)*
C. How will the results of research be made available to research participants and communities from which they are drawn?

No individual feedback will be given. The results as a whole will be documented in an easy-to-digest format available to everyone in the school community; they will be given firstly and directly to the participants (pupils, tutor, TA and SENCo) by the researcher so that any questions can be answered and the feedback amended if necessary before wider circulation.

D. What arrangements are in place for monitoring and auditing the conduct of the research?

Supervision by fieldwork placement supervisor, Manchester University supervisor, other university staff, the school SENCo and most immediately by the tutor/TA delivering the intervention.

E. What are the criteria for electively stopping the research prematurely?

Given previous preliminary work, it is not anticipated that the research will need to be stopped until at least the beginning of the intervention stage.

Then the criterion for stopping the research (or more likely adopting the contingency plan, see earlier appendix) will be: more than 10 students drop out, or the materials developed don't engage the class or more than a week of intervention is lost in a block to other school activities that were not planned around beforehand, or any participants sustain unforeseen harm that can't be resolved. (There is a school counsellor available should this unlikely event occur.)
9. Sponsorship
Provide information on whether the study is in receipt of any external funding.
Confirm who will act as sponsor of the research.
No external funding – the researcher is a student.

10. Conflict of Interest
Have any conflicts of interest been identified in relation to this project?
NO

SECTION 3 - MINOR AMENDMENT TO RESEARCH PROJECT

Application for Approval of Minor Amendment\(^{13}\) to a Research Study

*Details of proposed amendment (please give as much detail as possible)*

Supervisor Declaration

I agree that the amendment proposed does not change the character of this research or the participant groups.

I confirm that the research risk assessment for the study as MEDIUM remains.

<table>
<thead>
<tr>
<th>Supervisor’s signature*</th>
<th>Date.</th>
</tr>
</thead>
</table>

Please send applications for amendment to ethical approval for MEDIUM risk research to the School Quality Assurance Administrator at ethics.education@manchester.ac.uk who will pass on the request to the RIC member who authorised the original application wherever possible.

\(^{13}\) Minor amendments are those that do not alter the character of the research or the participant groups
Approval for research:

Ethical approval – email from Dr Laura Black:

Hi Susan

I’ve just sent my approval off to Gail who is the administrator for Ethics. You should receive an email confirming this but it can take a while to come through. Assume that you are good to go.

Thanks

Laura

(Role: Senior Lecturer Email: laura.black@manchester.ac.uk)
Minor amendment to research project

Application for Approval of Minor Amendment\textsuperscript{14} to a Research Study

Details of proposed amendment (please give as much detail as possible)

1) To use alternative pupil information and consent forms, as attached and approved by host school. The school was not happy with the length of the original draft – considered it to be inaccessible to some of their pupils and parents. 2\textsuperscript{nd} and 3\textsuperscript{rd} sheets are on school letter-headed paper.

2) To collect standardised data for all participants (as per baseline – NEPSY Inhibition subtest) if intervention continues to run smoothly for the whole class. Collection of additional data would be within form time and 1 PSHE lesson. School is happy with this arrangement.

Supervisor Declaration

I agree that the amendment proposed does not change the character of this research or the participant groups.

I confirm that the research risk assessment for the study as MEDIUM remains.

\begin{center}
\begin{tabular}{|c|c|}
\hline
Supervisor's signature* & Date. \\
\hline
K. Tyldeley & 10\textsuperscript{th} March 2014 \\
\hline
\end{tabular}
\end{center}

Please send applications for amendment to ethical approval for MEDIUM risk research to the School Quality Assurance Administrator at ethics.education@manchester.ac.uk who will pass on the request to the RIC member who authorised the original application wherever possible.

Approval for amendment

\textbf{From:} Ethics Education  
\textbf{Sent:} 23 May 2014 12:15  
\textbf{To:} susan darby  
\textbf{Cc:} Kathleen Tyldeley; Deborah Kubiena  
\textbf{Subject:} Ethical Approval - CONFIRMATION of amendments

Dear Susan
Ref: PGR-2075136-A1

Your amendment form relating to the above referenced application has been confirmed by the Manchester Institute of Education, Research Integrity Committee (RIC), This has been noted on your original approval/submission and you are able to continue with your research.

Regards

Gail

\textsuperscript{14} Minor amendments are those that do not alter the character of the research or the participant groups
Appendix 4: Appendices for Chapter 4

Appendix 4.1: Materials sent to experts before the first group interview

Table A4.1: Main sections of notes sent before the first expert group

<table>
<thead>
<tr>
<th>Basic shift task paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>- requires working memory, WM, (to process the new rule and activate the new S-R pair) and inhibition skills (to suppress previously relevant S-R pairings) in varying amounts, plus the skill to shift between mindsets (Davidson et al., 2006).</td>
</tr>
<tr>
<td>- the emphasis is on effortful moving between S-R &quot;grooves&quot;/mindsets and this requires top-down Executive Control (EC) (Davidson et al., 2006) also referred to as &quot;task control&quot; (Kalanthroff &amp; Henik, 2013; Kalanthroff et al., 2013).</td>
</tr>
<tr>
<td>- involves the presentation of successive visual stimuli each of which must be responded to according to a rule. The rule changes a number of times within a block of trials.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visual stimulus is presented:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- most, if not all, stimuli invoke (bottom up processing) at least two potentially conflicting tasks⁴ (or stimulus response pairs) because they have more than one visual dimension, for example, size, colour and shape(Kalanthroff &amp; Henik, 2013).</td>
</tr>
<tr>
<td>- this effect can be manipulated by changing the relative salience of the stimulus dimensions (Fisher, 2011), neutralising the content associated with a dimension (Kalanthroff &amp; Henik, 2013) or making the critical dimension predictable by having regular task switching (Kalanthroff &amp; Henik, 2013).</td>
</tr>
</tbody>
</table>

Judgement of stimulus dimension relevance dictated by simultaneous/ immediately preceding cue (interpreted according to rules). Cue examples: stimulus position, a letter or the background colour.

The relevant dimension is privileged within working memory:

- potential conflict between tasks is thus managed and by a top-down EC process (Davidson et al., 2006; Kalanthroff & Henik, 2013)⁴.
- this narrowing of focus could be achieved by suppression of: particular stimuli dimension processing, irrelevant cognitions or inappropriate responses⁵ (Ikeda et al., 2013) .
- EC is less efficient in those with poorer inhibition skills (Kalanthroff & Henik, 2013).
- the degree of engagement of EC varies according to context. It is reduced where stimuli are free from conflict, and/or where the change in relevant stimulus dimension (ie switch) is predictable⁷(Kalanthroff et al., 2013).

Response is made
Table A4.1: continued

Diagram annotations:

a: For example, the words presented in the colour Stroop task induce word reading and colour judgement tasks. In the congruent condition the two tasks are not in conflict, because they produce the same information. However in the incongruent condition the two kinds of information are in conflict (Kalanthroff & Henik, 2013).

b: Neuroimaging data suggests that this “task control” function is always activated where there are two potentially conflicting tasks (see Kalanthroff, Goldfarb, Usher, & Henik, 2013). It could add brain areas – and check that are exactly the same as EC!

c: In more detail, Ikeda, Okuzumi, & Kokubun (2013) suggest that selective focus at this stage could be due to:
   i) suppression of interference from irrelevant aspects of the stimulus. Here the distractors are considered to be simultaneous: they are the different visual/semantic dimensions. They consider this to be particularly relevant in the Flanker task. This is equivalent to switching and selectively attending to particular features of a stimulus, inhibitory control and selective attention being two sides of the same coin (Ikeda et al., 2013). Similarly, Davidson et al. (2006) argue that it is the ability to inhibit attention to distractors that allows selective and sustained attention and Hu et al. (2013) argue that the executive control of attention involves selectively looking at particular aspects of a stimulus and ignoring others. For some authors this is sufficient to underpin successful task switch (Hester & Garavan, 2005); for others it explains performance on inhibition tasks (Hu et al., 2013).
   ii) suppression of the irrelevant cognitions. Here the distractors are considered to have arisen prior to the stimulus presentation; they could be previously relevant task rules. Zelazo et al. (2003) would also suggest they could be any S-R pairs that are not currently useful.
   iii) suppression of response. Here the distractors are currently incorrect responses; they are particularly interfering if they have been built up through training or they are the prepotent/natural response to the relevant stimulus dimension (Ikeda et al., 2013). This is considered to be particularly relevant in the StopSignal, GO-NOGO and Stroop tasks. Davidson et al. (2006) go so far as to say that the ability to inhibit a strong behavioural inclination allows the possibility of change as well as social politeness.

   Whilst they try to break down the task of inhibition, Ikeda et al. (2013) also acknowledge that the first and third aspects are at least very closely related. The evidence from Kalanthroff and colleagues (Kalanthroff & Henik, 2013; Kalanthroff et al., 2013) supports this: it suggests that irrelevant dimensions of the stimulus can never be fully suppressed. Put differently, selective attention is never perfect. Crone, Bunge, van der Molen, & Ridderinkhof (2006) suggest that inhibition is about the repression of a stimulus-response pair (S-R pair) which equally implies that stimuli and their responses cannot be considered separately.

d: Evidence for this idea comes from tasks where reverse facilitation can be induced by catching the “task control” off-guard by using a high proportion of neutral stimuli.

   Given the EF skill blend required in Switch tasks, we would expect practice benefits to extend to WM and inhibition, as well as Shift itself. But with the need to confine this intervention to discrete small time slots, generalisation beyond similar tasks is unlikely.

A switch/shift task can be made more difficult by:

- having a partial rather than complete task switch (Davidson, Amso, Anderson, & Diamond, 2006). This way multiple S-R pairings are potentially invoked. This includes using:
   - the same stimuli for different tasks, such that different dimensions become successively relevant. (Zelazo et al., 2003; Davidson et al., 2006)
   - changing some of the responses required in a task. For example, adding in GO/NOGO response types (Huizinga & van der Molen, 2011) - requiring the same responses to different tasks; younger children find this particularly difficult (Crone et al., 2006). One example is Davidson et al.’s (2006) supposed WM loaded task, where identification of 3 different items all require the same key press.
   - manipulating the working memory requirement. It can be reduced by providing a cue for which rule is to be used in the task and/or by having a reminder available for what response is expected for each stimulus decision. It can be increased by giving more rules. (Children as young as four years can manage two rules if they are not being asked to inhibit a prepotent response (Davidson et al., 2006).) It can also be increased by adding in secondary working memory tasks (Hester & Garavan, 2005).
   - manipulating the inhibition requirement. This can be increased by including S-R pairings that involve prepotent or previously well learnt responses (Ikeda et al., 2013) although this effect is reduced with increasing age (Davidson et al., 2006). Examples include a tendency to read the word rather than say the colour in Colour Stroop and a tendency to give a response on the ‘same side’ as a stimulus appears (the Simon Effect).

   Particular response patterns emerge if a prepotent response is required some of the time, i.e where response shift occurs within trials blocks. In adults, local shift costs are greater to the prepotent response. This is generally interpreted to mean that adults’ well developed ability to inhibit will have been more strongly invoked for a prepotent response and that letting go of this requires more effort (Davidson et al., 2006). Some researchers have found the same effect in children (Crone et al., 2006; Huizinga & van der Molen, 2011) and suggest that this reflects a general mechanism implicated in all switch and shift tasks that is needed to actively select, prepare and execute a response after not needing it. However, in Davidson et al.’s (2006) study young children always found it easier to give the prepotent response, this reflecting their lesser inhibition skills. These author’s found that somewhere between 8 and 13 years, children gave an extreme adult response pattern interpreted as a reflection of the additional effort needed at this age (Davidson et al., 2006).

- having a varied and unpredictable number of trials between task switches (Davidson et al., 2006; Huizinga & van der Molen, 2011)
- varying the relative saliences and weightings of stimuli dimensions. It is harder to switch to a task where the saliency of the relevant stimulus dimension is lower, especially for young children (Fisher, 2011). Also, it is harder to switch when all relevant dimensions have very few values, as the weighting given to each is greater (Fisher, 2011).

- making the switch task composite. Switching between main tasks and between emphasis in response is one possibility. Gopher, Greenshpan and Armony (1996) had main tasks of evaluating the size of a number or the number of digits, with a change in response emphasis between accuracy and speed; both Switch types exacted a cost. Alternatively participants can be asked to switch between main task and response mode. Huizinga & van der Molen (2011) had main tasks of evaluating shape or colour, with a change in response mode between always giving an answer and with holding a response in specified situations (GO/NOGO).
### Table A4.1: continued

Matrix framework of task characteristics, populated by some examples

<table>
<thead>
<tr>
<th>Task:</th>
<th>Switch/shift difficulty level</th>
<th>WM load</th>
<th>Inhibition difficulty</th>
<th>Loading on non-EF skills</th>
<th>All logistics suitable for this intervention.</th>
<th>Likely Learning Hierarchy stage</th>
<th>Relative stimuli dimension saliencies</th>
<th>Type of S-R pair changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 abstract shapes (Davidson et al., 2006)</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>Low</td>
<td>Y – with modifications</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pictures (Davidson et al., 2006)</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>Low</td>
<td>Y – with modifications</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Arrows (Davidson et al., 2006)</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>Low</td>
<td>Y – with modifications</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Dots mixed (Davidson et al., 2006)</td>
<td>3</td>
<td>1/2</td>
<td>3</td>
<td>Low</td>
<td>Y – with modifications</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Dots congruent and incongruent (Davidson et al., 2006)</td>
<td>1</td>
<td>1</td>
<td>1 or 3</td>
<td>Low</td>
<td>Y – with modifications</td>
<td>1</td>
<td>1 or 2</td>
<td></td>
</tr>
<tr>
<td>Contingency card naming (as in Pilot)</td>
<td>3</td>
<td>1 or 2</td>
<td>1</td>
<td>Low if suggested presentation changes made</td>
<td>Y</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Verbal sequences (as in Pilot)</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>High so only for those confident with alphabet order</td>
<td>Y?</td>
<td>2</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Trailmaking (as in Pilot)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>Medium?</td>
<td>Y – and could make better</td>
<td>2</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Knock and tap (as Pilot)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Low</td>
<td>Y</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Stroop (as in Pilot)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Low</td>
<td>Y – and could turn into true shift task</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Flanker (as in Pilot)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Low</td>
<td>Y</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
### Table A4.1: continued

<table>
<thead>
<tr>
<th>Switch/shift difficulty:</th>
<th>1 = switch/shift between trial blocks – not really a Shift task, as laid out in basic paradigm</th>
<th>2 = regular switch/shift within trial blocks</th>
<th>3 = irregular switch/shift within trial blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM load:</td>
<td>1 = high meaning cues and single level task</td>
<td>2 = no/low meaning cues or composite task with high meaning cues</td>
<td>3 = composite task with no/low meaning cues (or additional secondary WM task added in)</td>
</tr>
<tr>
<td>Inhibition difficulty:</td>
<td>1 = no prepotent or well-rehearsed responses involved (or all prepotent responses involved)</td>
<td>2 = a proportion of the responses involved are prepotent or well-rehearsed</td>
<td></td>
</tr>
<tr>
<td>Type of S-R pair changes:</td>
<td>1 = no stimulus or response is involved in more than one than one S-R pair</td>
<td>2 = stimuli and/or responses are used more than once, so that competing S-R pairs are invoked</td>
<td></td>
</tr>
<tr>
<td>Relative stimuli dimension saliencies:</td>
<td>1 = similar saliencies</td>
<td>2 = one (or more) dimensions are obviously more salient</td>
<td></td>
</tr>
<tr>
<td>Loading on non-EF skills – should be low for all. Stimuli must be easy to see and handle and must not involve high levels of literacy, numeracy or problem solving skill.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistics – as indicated by the Pilot:</td>
<td>- task blocks can fit several times into in a 15 minute slot</td>
<td>- task is suitable for working in pairs</td>
<td>- task is suitable for easy collection of performance data, such as number of errors and time to complete trial block</td>
</tr>
<tr>
<td>Likely Learning Hierarchy stage: Shift skills exist in 3 year olds; likely stages for adolescents are Generalisation and Adaptation?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This matrix should help to generate the sequencing of tasks within the intervention. Tasks that load heavily on all of switch/shift difficulty, WM load, inhibition difficulty, dimension salience differences and S-R partial changes will be the most difficult of all. Also tasks can be modified so as to ensure coverage of all difficulty levels. It is important to remember that the Pilot tasks seemed about the right level of difficulty: they could be engaged with, but there was challenge. There the participants were Year 7s of lower middling ability, as determined by Key Stage 2 SATs results.
### Table A4.2: Revised matrix with tasks inserted. *(Italics: task not used in Darby, 2013a,b)*

<table>
<thead>
<tr>
<th>Shift 1</th>
<th>Shift 2</th>
<th>Shift 3</th>
<th>Shift 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WM1</strong></td>
<td><strong>WM1</strong></td>
<td><strong>WM2</strong></td>
<td><strong>WM3</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I1</td>
<td>I2</td>
<td>I3</td>
<td>I1</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1a</td>
<td>2a</td>
<td>1b</td>
<td>2b</td>
</tr>
</tbody>
</table>
| Contingency card naming items – for whole sheet name shape or colour. *(Equivalent to DCCS).* Flanker sheets – for whole sheet name inside or outside shape. Stroop sheets. *Day/night sheets. Dots sheets.* Trailmaking. Flanker sheets with cues. Contingency card naming sheets with cues. Global/local shape sheets with cues. Stroop sheets with cues. *Day/night sheets with cues.* Stroop sheets with cues. *Day/night sheets with cues.* Contingency card naming with cues. 'Dots mixed' Knock and tap contingency card naming – low meaning cues. Number judgements with cues. '6 abstract shapes.' Composite contingency card naming. 6 abstract shapes. Contingency card naming – low meaning cues and remember NOGO every 4. 4b2 and cued NOGO. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes.
<p>| | | | | | | | | | | | |
| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th>I2</th>
<th>I3</th>
<th>I2</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
<th>I3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>1b</td>
<td>2b</td>
<td>1c</td>
<td>3b</td>
<td>1d</td>
<td>5b</td>
<td>3a</td>
<td>4a</td>
<td>4b</td>
<td>6a</td>
<td>7</td>
</tr>
<tr>
<td>Stroop sheets. <em>Day/night sheets. Dots sheets.</em> Stroop sheets with cues. Stroop sheets with cues. Contingency card naming with cues. 'Dots mixed' Knock and tap contingency card naming – low meaning cues. Stroop sheets with cues. <em>Day/night sheets with cues.</em> Stroop sheets with cues. <em>Day/night sheets with cues.</em> Contingency card naming with cues. 'Dots mixed' Knock and tap contingency card naming – low meaning cues. Number judgements with cues. '6 abstract shapes.' Composite contingency card naming. 6 abstract shapes. Contingency card naming – low meaning cues and remember NOGO every 4. 4b2 and cued NOGO. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. 6 abstract shapes / Contingency card naming mixes. Non-cued contingency card naming/Stroop mixes with NOGO to remember eg every 4th or 6a2 with NOGO to remember 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shift 1</td>
<td>Shift 2</td>
<td>Shift 3</td>
<td>Shift 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Appendix 4.2: Additional materials developed for the second expert group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Figure A4.1: Examples of particular tasks

1. **Contingency Card Naming – with low WM load cues** – S/C for shape or colour

   **Original task stimuli**
   
   ![](image1)

   **Task 1a: sheets – name either colour or name.** (Functionally equivalent to Dimensional Change Card Sort (DCCS) Test – Zelazo et al., 2013)
   
   ![](image2)

   **Task 1b:**
   
   ![](image3)

   or **Task 1b:**
   
   ![](image4)

   **Task 1c – cards as original task stimuli – see top**

   **Task 1d – mix two C/S sets**
   
   or mix original C/S with cued Flanker cards
   
   ![](image5)

   **Task 2b2 – use sheets from 1a and remember to switch alternately.**

   **Task 3a2 - use sheets from 1a and remember to switch every 2/3/4.**

   ![](image6)
## Appendix 4.3: Materials taken to the stakeholders’ group

### Table A4.3: The task matrix presented to the stakeholder group

<table>
<thead>
<tr>
<th></th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>1</th>
<th>1</th>
<th>I2</th>
<th>I3</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM1</td>
<td></td>
<td>1a: task set 1+2 practice sheets = sheets 1. Set 1: Contingency card naming - high meaning cues - C/S (equivalent to DCCS) and I/O (Flanker). Set 2: low meaning cues - background colour, item position.</td>
<td></td>
<td>2a: task set 3+4 practice sheets = sheets 1. Set 3: high meaning cues ie colour Stroop and Location Stroop. Set 4: low meaning cues sheets - Dots.</td>
<td>1b: task A - task set 1 sheet 2 with regular cue switch.</td>
<td></td>
<td>2b1: task D - task set 3 sheet 2 with regular cue switch.</td>
<td></td>
<td>1c: task B – set 1 cards 1.</td>
<td></td>
<td>3b1: task I – set 3 cards 1.</td>
<td></td>
<td>1d: task C - set 1 mix 1, 2, 3.</td>
<td></td>
<td>5b1: task N - set 3 = mixN1 - set 1/3 mixes, mix N2, N3</td>
<td></td>
</tr>
<tr>
<td>WM2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2b2: task E - task set 1 and remember to alternate. Use sheets 1 from 1a. - task set 2 sheet 2 with regular switch.</td>
<td></td>
<td>3a1: task F - task set 3 and remember to alternate. Use sheets 1 from 2a. - task set 4 sheets 2 with regular switch.</td>
<td></td>
<td>3b2: task J – set 2 cards 1.</td>
<td></td>
<td>4b1: task K – set 4 cards 1. - set 1/3 cards 2 with irregular NOGO cue (regular isn’t guaranteed with cards).</td>
<td></td>
<td>5b2: task O - set 2 mix = mix O1 - set 1/2 mixes, mix O2, O3</td>
<td></td>
<td>6a1: task P - set 2/4 mixes = mix P1 - set 2/4 mixes with irregular NOGO cue = mixP2 - set 1/3 mixes with NOGO remembered = Mix P3</td>
<td></td>
</tr>
<tr>
<td>WM3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3a2: task G - task set 1 and remember to switch every 4. Use sheets 1 from 1a. - task set 5: 6 abstract shapes + number judgements– (practice) sheets 1 with regular response shift.</td>
<td></td>
<td>4a: task H - task set 3 and remember to switch every 4. Use sheets 1 from 2a.</td>
<td></td>
<td>4b2: task L - Composite from sets 2, cards 2. - set 5 cards 1.</td>
<td></td>
<td>5a: task M - set 2 cards 3 and set 4 cards 2 with irregular NOGO cue - set 5 cards 2 (just 6 abstract shapes) with Simon effect.</td>
<td></td>
<td>6a2: task Q - set 5/other mixes, mix Q1, Q2 - all set mix, mix Q3</td>
<td></td>
<td>7: task R - as above with Simon added to 6 abstract shapes and NOGO to others, mix R1, R2. - all set mix with NOGO remembered, mix R3</td>
</tr>
</tbody>
</table>
### Table A4.4: The core intervention tasks

<table>
<thead>
<tr>
<th>Core tasks</th>
<th>Task characteristics re EF</th>
</tr>
</thead>
</table>
| Card naming:  
C/S (colour/shape) circles and triangles  
C/S stars and cubes,  
I/O (inside/outside) shapes | Have high meaning cues (low Working Memory load) and do not involve prepotent responses (so low Inhibition load) – set 1. |
| Card naming:  
Digit in shape  
Objects in frame | Have low meaning cues (so medium Working Memory load) and don’t involve prepotent responses (so low Inhibition) – set 2. |
| Colour Stroop  
location Stroop | Have high meaning cues (so low WM load) and involve prepotent responses (so high Inhibition) – set 3. |
| Dots | Tasks have low meaning cues (so medium WM load) and involve prepotent responses (so high Inhibition) – set 4. |
| Abstract shapes  
Number judgements | Tasks have high WM loading and don’t involve prepotent responses (so low Inhibition) – set 5. |
At this point the pages were A5 size. The second page shows the 'test task' that was to collect the Time Series data.
Figure A4.3: Examples of the tasks suggested by the pre-prototype

Flanker as task G.
Rule: say the inside shape, inside, inside, inside, outside shape, outside, outside, outside, inside, inside, inside ... until the end of the sheet.

Contingency naming - object in frame, as task E.
Rules: At the top – say the number. At the bottom – say the object
Appendix 4.4: Example of annotated transcript

Figure A4.4: Annotated transcript from the second expert group

In that I’ve said that some of the things need to be at certain levels like requirement for visual discrimination and all that kind of thing, should all be at a low level regardless, and therefore it doesn’t actually need to be in a matrix. The things that need to be in the matrix are obviously - how difficult shift is, but then if we’re talking about a central executive that has a limited capacity, it seems to me then, it’s kind of what I was talking about last time which is you’ve got restricted capacity which has got to cope with switching and inhibition and working memory.

Any kind of morphs around depending on the particular tasks requirements.

Yeah, yeah.

Right, Ok. So over down in the bottom right-hand corner, are the tasks that are high on working memory, inhibition and shift, and if you could do those you’d actually be kind of working the muscle and make the whole thing bigger.

Yeah, increasing fundamental attention capacity.

Yes as opposed to the things down this end which are not even shift tasks almost, they’re just sort of, well as it says, the practise tasks that allow you to then move on to shift.

Yes, so they’re more aimed at the practical side of things and Yeah.

An introductory activity to help the kids and teach them to understand what it is that the task requirements will be?

Yeah.

So that’s more for understanding instructions rather than rehearsing any of the tasks that you’re going to ask them to do?

In a way, and I wondered about, and I’m sure you’ll have a view on this Richard, and you as well Kath, but last year we talked about having maybe a more limited number of tasks and using them more than once, and using sort of like the beginning bit of the matrix as a chance to get familiar with the different tasks that will be involved.

Mmm.

So although I know I have actually still sent you quite a lot of different tasks, actually I could say “right let’s go for a couple that represent low inhibition”, and then you’ve got a couple like the Stroopy ones and arguably, I haven’t used it before of course, this Day/Night thing - has got more inhibition involved in it, so you’ve got more, a couple there, but both, all of those, whether the low or the increased inhibition can then be increased in their shift difficulty and potentially working memory. Does that make sense?

Yeah.

By doing so, by having it in this matrix, what you would be fundamentally doing by having that stepped approach, is working the overall capacity, yeah, fundamentally increasing that Central Executive and executive function and attentional capacity but with the likes of 1b and 2b and even 1c, it’s really working on the meta-cognitive aspect of it because kids are, will be very aware of the difference between those tasks, how are they finding these individual tasks a little bit easier because of lessening load based on working memory and things like that.

Yeah.

So they will start to have that intuitive understanding of why these tasks are varying in their difficulty.

That will be really interesting actually to see if that conversation comes out won’t it?

Yeah.

Red = initial paraphrasing; black = themes/codes. Usually these are in the right and left margins respectively.
Appendix 4.5: Examples of initial and intermediate thematic maps

Figure A4.5: Initial thematic map from the second expert group
Figure A4.6: Intermediate thematic map from the stakeholder group
### Appendix 4.6: Examples of excerpts for final themes/codes

#### Table A4.5: Examples of codes per theme – from the stakeholder group

<table>
<thead>
<tr>
<th>Getting a feel</th>
<th>What students do</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cues</strong>: So the 'S' is for shape</td>
<td></td>
</tr>
<tr>
<td><strong>Errors</strong>: Do you want them to record the mistakes on like a tally or something? .. So they need a bit of paper to do that on? .. when do they revisit this?</td>
<td></td>
</tr>
<tr>
<td><strong>Self-management</strong>: So are these all different sorts of tasks, then that they are going to work through .. It's the same sort of format they can jump around can’t they, say if they leave some?</td>
<td></td>
</tr>
<tr>
<td>How easy is this to understand in regards to that, so .. Task C uses tasks from Set 1, so I go to .. so if I go to that now I should be able to find those relatively easily they'll say &quot;Sir I don’t get this&quot; .. They're not allowed to do that are they if they are self-managing it all they need to get stuck then get unstuck don't they?</td>
<td></td>
</tr>
</tbody>
</table>

| What facilitators do | |
| are you coming in to explain to the students or is xx or yy going to be the person who stands there and explains what the process is? |
| I think you definitely need to know all these tasks and how they work so, because you know that as soon as the kids start initially they're just going to go "whoooo" if it’s not immediately apparent and clear and simple |

| Seeing is believing | |
| Would it be possible to get a copy of it, of all this material so we can actually have a go |
| We could do with some kids to have a go .. Yeah a little group to trial them. |
| We need to have a little go at it definitely |
| I need to get my head, have a go at it, that's what I need to do .. I need to see some kids doing it. |
| we could do is just get a sample few kids to just say "Right, this is an activity we want you to try, there's the booklet, there's the boxes, you go and .. And see if they can do that. I'd like to see that happen before I go in and start the work really. |

<p>| What materials needed | |
| how many sets would we need for the whole class? |
| Will you be producing those |
| Are we going to have them in different boxes for different levels? |</p>
<table>
<thead>
<tr>
<th>Student needs</th>
<th>Materials easy to self-manage: to locate and with minimum info</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>you know that as soon as the kids start initially they're just going to go &quot;whoooo&quot; if it's not immediately apparent and clear and simple .. I don't know if that's student-friendly or not. I need that set of cards and a timer and that's it. Less information, just go to Box with Task A written on, do the activity .. the less reading on it the better .. reduce the literacy demand .. it might create loads of boxes but .. that's more obvious as a child would think</td>
</tr>
<tr>
<td></td>
<td>Sense of progress and ownership</td>
</tr>
<tr>
<td></td>
<td>I like the idea of the booklet 'cos then they've got the ownership</td>
</tr>
<tr>
<td></td>
<td>If they're self-managing this though, I don't think they would, some would some wouldn't. .. they'll say &quot;Sir I don't get this&quot; .. They're not allowed to do that are they if they are self-managing it all</td>
</tr>
<tr>
<td></td>
<td>make the booklet smaller but more of them, so they're progressing through booklets as well and think &quot;Oh I'm on booklet 3 or &quot;</td>
</tr>
<tr>
<td></td>
<td>Acceptability</td>
</tr>
<tr>
<td></td>
<td>, I do it in some of my lessons reduce it to A5 but if I'm completely honest, I'm moving away from that and I'm putting everything on A4 now. But the kids were like &quot;I can't see this graph, reducing the number of tasks on a page .. 'cos that booklet is then going to treble is size isn't it potentially? Is that a bit scary? .. No 'cos it's over 6 weeks isn't it. They'll just accept it won't they, if we just tell them we're doing it, they'll just say &quot;Yeah, we're doing it&quot;. .. They're not going to know any different , they'll think &quot;Ooh&quot;</td>
</tr>
<tr>
<td></td>
<td>Usability of cards</td>
</tr>
<tr>
<td></td>
<td>like the feel of card but are they durable enough? It depends how many times they do it ... When I tried stuffing the card back in the envelope I thought it's fine when they get them out and use them, it's probably the stuffing them back in that might ... the thicker the better really isn't it .. the laminate doesn't feel that nice does it, I agree but it might just last? the corner nicked out which tells them which way up to hold them .. I like that idea actually .. (which corner?) .. I don't think it would matter would it? Ideally you'd have them all the same but so long as they're all the same with a pack of cards sort of look .. if they had to do it that way, as long as I know I'm doing it all that way. .. Leave the other ones that way .. See I'm tending to turn these that way round .. they go better in my hand .. So maybe the kids will do that</td>
</tr>
<tr>
<td></td>
<td>Oh no, they're all weird .. As a deck of cards, as the kids are used to handling those, that way as well aren't they if they play cards?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Staff Anxiety</th>
<th>Own exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>That's what I'm fearing actually. So we'll be really rubbish at it. I don't want to know what I am. If I'm somewhere up here then ... I'll be honest! I had a look at it before, that one, and I'm thinking &quot;Jesus!&quot;, yeah</td>
</tr>
<tr>
<td></td>
<td>Chaotic classroom</td>
</tr>
<tr>
<td></td>
<td>I think you definitely need to know all these tasks and how they work so, because you know that as soon as the kids start initially they're just going to go &quot;whoooo&quot; if it's not immediately apparent and clear and simple Full of cards - all over the floor Well I can put them onto 5 tables and have one set per table if that makes life easier, so they're not wandering around the classroom getting sheets from there, cards from this one, I don't know how that's all going to ...... so the logistics of all that, I don't know how that would work. .. If I dish all that out to the kids, I wouldn't do that actually 'cos I could just see everything getting lost and I think it would just turn into chaos Or if we did so many tasks per day and just gave them the cards for those 3 tasks would that make life easier? .. We wouldn't need them all out then. I know some might jump ahead but if the kids hold on to their set of cards .. we need to drum that into them I don't know how you're going to keep this organised, I'm terrified .. If think if they're in their own box though them cards will go back in that box so that'll be fine .. Make sure your cards go back in the appropriate box</td>
</tr>
</tbody>
</table>
Appendix 4.7: Samples of the prototype materials

Figure A4.7: The first four pages from the student booklet
Figure A4.8: Example of card-based task including a rule card

These are just four of the cards from the task – once printed they would also have the top right corner removed.

**Flanker as task B**

<table>
<thead>
<tr>
<th>IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="IN-Shape" /></td>
<td><img src="image2" alt="OUT-Shape" /></td>
</tr>
</tbody>
</table>

**Rule card**

- IN - say the inside shape.
- OUT - say outside shape

- **IN** - “circle”
- **OUT** - “triangle”

*Shuffle the cards*
Figure A4.9: Example of sheet-based tasks

Flanker as task G

Colour Stroop as task F
### Essential Administrator Hints

1. Prime the students to look for:
   - rule cards in the card sets – they should be easy to find, as they haven’t had a corner chomped, and
   - rules at the bottom of the sheets
2. Make sure students realise they can do the tasks on a page in any order – this will stop a problem over everyone wanting the same materials
3. Encourage the students to be as accurate they can and then to see if they can speed up
4. If students are making a lot of mistakes, encourage them to slow down and focus on accuracy and do all the tasks at each level (rather than being selective and jumping up levels)
5. If students are finding the tasks easy, encourage them to pick one from each level and move up the levels quickly – and perhaps do 2/3 each day
6. Encourage discussion of which tasks are harder and why
7. If certain tasks are off-putting to particular students – for example, the maths tasks or those needing left/right (dots) – encourage them to try the other tasks on the same page, so that at least one is completed for each level
8. Prime students that the test page is at the back – and should be visited on the dates given
Appendix 4.8: Hypothetical example of an intervention session

The student enters the form room to find booklets, stop-clocks and task materials placed on a table. They collect their booklet and a stop-clock, unless their partner has already picked these up. The front cover of the booklet is reproduced below.

The student and his/her partner open up their booklets and agree on a task to work on. This could be ⭐️ B on page 4, see below.
The instructions say “You need: ⭐ B cards and 🌟”. The students have their stop-clock already. One of the pair will fetch a set of ⭐ B cards from the box labelled ⭐ B. Examples of the cards are shown below. The actual cards have a corner notch removed to allow quick orientation of the complete pack.

The back of every card for this task looks the same, so that tasks can be kept separate relatively easily:

The pair look for the rule card, see below. This does not have a notch removed, so can be located relatively quickly.

S - say the shape.
C - say the colour.

“pink”
“cube”

Shuffle the cards

The first student of the pair will carry out the task, whilst the second times them and monitors the number of errors made. At the end of the task, they feedback
this information to the first student who completes part of the corresponding table, see below. Typically the task will have taken less than a minute.

<table>
<thead>
<tr>
<th>Date</th>
<th>How long? In seconds</th>
<th>How many errors?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st go</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd go</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The pair members swap roles and repeat the task three times, such that each student will have completed their table for the task.

They will then choose another task, perhaps $\text{C}$ from page 5. Again following similar instructions in the booklet, one of the pair will fetch a set of $\text{C}$ cards from the box labelled $\text{C}$. Examples of the cards are shown below. Again, the actual cards have a corner notch removed to allow quick orientation of the complete pack.

![Card Examples](image)

Again, the back of every card for this task looks the same, so that tasks can be kept separate relatively easily:

![Rule Card Example](image)

Again the pair locate the rule card, see below. Again it does not have a notch removed.
IN - say the inside shape.
OUT - say outside shape
S - say the shape.
C - say the colour.

OUT

"triangle"

C

"pink"

Shuffle the cards

The students carry out the new task in a similar way. Once they have completed it, it is likely that form-time will be finishing; they will have been chatting alongside carrying out the tasks. They would return the materials, the booklet and the stop-clock to the table ready for the facilitator to put them away.
Appendix 4.9: Information provided to participants after the end of the intervention

Figure A4.10: Anonymised* example of personalised feedback letter

Thank you X for taking part in my thinking skills research. You have been understanding and patient in helping to find out what works and your views will be used to shape future research.

The ‘Shifty Thinking’ tasks that you have tried out aim to boost Executive Function skills. These are the thinking skills needed when instinct and intuition are not enough. They include working memory and the ability to shift between response patterns. They are linked to many life outcomes including academic achievement.

You are amongst the first people in the world to have been involved in a trial that is school-based and aimed at students of your age.

So again a big thank you.

Researcher signature

Doctoral student in Child and Educational Psychology

If you want to know more, then please contact me at: susan.darby@postgrad.manchester.ac.uk

You will receive some more information before the end of term about the outcomes from this stage of research.

*The actual letters also contained the University and School logos.
What was the research trying to find out? This research was trying to find out whether some particular thinking skills known as Executive Function skills can be boosted in students of secondary school age. Executive Function skills allow us to mentally play with ideas, to give ourselves time to think before we act, meet new and unexpected challenges, to resist temptation and to stay focussed. They help students do well in school.

Who took part and what did they do? Mr Z’s Year 8 class used form time, three times a week for 6 weeks, to have a go at some tasks designed to improve Executive Function skills. Although the students largely managed the research activities themselves, Mrs Y made sure that the whole process ran smoothly.

Did it work? In terms of the measures, yes! Three particular skills were measured before and after the intervention:

1. Naming: being able to identify and name items quickly and accurately.
2. Inhibition: being able to resist giving an automatic response.
3. Shift: being able to respond flexibly.

The graph shows that on average the students got better at all of the skills, and two of these results are strong enough for other researchers to take note of them. For research that has taken place in busy school environment, with all of the difficulties that go with that, these results are very positive.
The ways in which students’ measured skills changed varied considerably, but overall, it seems that self-monitoring skills were particularly affected. However, it is difficult to say that these apparent skill improvements have produced benefits beyond the measures, for example in the classroom.

**What did the students think?** Some members of Mr Z’s’ form took part in short group interviews. The messages they gave were clear and more-or-less unanimous. These are the main ones:

- It is difficult to see how these activities relate to real life, because they seem really different from what we do day-to-day.

- At the start the research activities were interesting, because they were new. As time went on, they became boring. So next time, add in more variety.

- Self-managing the activities was good, especially in form time. It meant they could be fitted in with catching up with news, and friends could work together. Some boys thought it would be OK to be paired up by a member of staff instead of choosing partners themselves.

**What next?** The intention is to publish this research in a research journal. Perhaps other researchers will be tempted to pick up “Shifty Thinking” and improve it for trials in other schools.

If you want more information, please feel free to contact me:

susan.darby@postgrad.manchester.ac.uk

It has been a good experience to carry out research at The …… School. Everyone has been really helpful, staff and students alike. Thank you!

*Researcher signature*

Doctoral student in Child and Educational Psychology

*The actual feedback contained the University and School logos*
Appendix 4.10: Quantitative data detail

Table A4.7: Raw and standardised (including corrected retest) scores for each participant

<table>
<thead>
<tr>
<th>Child</th>
<th>Pre-test time/s</th>
<th>Pre-test no. errors</th>
<th>Pre-test combined scaled score</th>
<th>Retest time/s</th>
<th>Retest no. errors</th>
<th>Retest combined scaled score</th>
<th>Retest combined scaled score with time and error component corrections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>0</td>
<td>9</td>
<td>39</td>
<td>0</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>9</td>
<td>3</td>
<td>47</td>
<td>0</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>43</td>
<td>2</td>
<td>5</td>
<td>33</td>
<td>1</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>2</td>
<td>8</td>
<td>30</td>
<td>1</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>55</td>
<td>2</td>
<td>4</td>
<td>45</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>1</td>
<td>8</td>
<td>32</td>
<td>1</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>44</td>
<td>2</td>
<td>5</td>
<td>40</td>
<td>0</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>48</td>
<td>8</td>
<td>3</td>
<td>33</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>47</td>
<td>7</td>
<td>3</td>
<td>39</td>
<td>2</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>47</td>
<td>1</td>
<td>7</td>
<td>42</td>
<td>0</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td>3</td>
<td>6</td>
<td>37</td>
<td>1</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>13</td>
<td>41</td>
<td>2</td>
<td>6</td>
<td>34</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>38</td>
<td>4</td>
<td>5</td>
<td>37</td>
<td>1</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>72</td>
<td>2</td>
<td>2</td>
<td>50</td>
<td>0</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
<td>47</td>
<td>1</td>
<td>6</td>
<td>40</td>
<td>0</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>17</td>
<td>43</td>
<td>5</td>
<td>4</td>
<td>40</td>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>42</td>
<td>0</td>
<td>10</td>
<td>36</td>
<td>1</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>19</td>
<td>74</td>
<td>1</td>
<td>4</td>
<td>53</td>
<td>1</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>42</td>
<td>2</td>
<td>6</td>
<td>43</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>43</td>
<td>2</td>
<td>5</td>
<td>40</td>
<td>0</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>22</td>
<td>45</td>
<td>2</td>
<td>4</td>
<td>41</td>
<td>0</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>23</td>
<td>41</td>
<td>3</td>
<td>4</td>
<td>33</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Child</td>
<td>Pre-test time/s</td>
<td>Pre-test no. errors</td>
<td>Pre-test combined scaled score</td>
<td>Retest time/s</td>
<td>Retest no. errors</td>
<td>Retest combined scaled score</td>
<td>Retest combined scaled score with time and error component corrections</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>-------------------------------</td>
<td>---------------</td>
<td>------------------</td>
<td>-----------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>70</td>
<td>6</td>
<td>4</td>
<td>57</td>
<td>1</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>76</td>
<td>5</td>
<td>4</td>
<td>82</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>68</td>
<td>3</td>
<td>7</td>
<td>37</td>
<td>0</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>47</td>
<td>3</td>
<td>10</td>
<td>30</td>
<td>0</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>62</td>
<td>5</td>
<td>6</td>
<td>66</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>57</td>
<td>4</td>
<td>7</td>
<td>38</td>
<td>2</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>2</td>
<td>11</td>
<td>58</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
<td>3</td>
<td>7</td>
<td>50</td>
<td>2</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>6</td>
<td>5</td>
<td>49</td>
<td>0</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>59</td>
<td>0</td>
<td>12</td>
<td>54</td>
<td>0</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>53</td>
<td>5</td>
<td>6</td>
<td>48</td>
<td>5</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>42</td>
<td>5</td>
<td>9</td>
<td>35</td>
<td>0</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>58</td>
<td>3</td>
<td>8</td>
<td>49</td>
<td>2</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>87</td>
<td>4</td>
<td>6</td>
<td>72</td>
<td>1</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>73</td>
<td>5</td>
<td>6</td>
<td>52</td>
<td>1</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>17</td>
<td>58</td>
<td>5</td>
<td>7</td>
<td>52</td>
<td>2</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>18</td>
<td>54</td>
<td>2</td>
<td>9</td>
<td>52</td>
<td>1</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>19</td>
<td>85</td>
<td>4</td>
<td>6</td>
<td>100</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>64</td>
<td>7</td>
<td>5</td>
<td>60</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>21</td>
<td>70</td>
<td>8</td>
<td>3</td>
<td>56</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>22</td>
<td>72</td>
<td>0</td>
<td>11</td>
<td>65</td>
<td>0</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>23</td>
<td>60</td>
<td>3</td>
<td>8</td>
<td>52</td>
<td>0</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>
Table A4.7 continued

<table>
<thead>
<tr>
<th>Child</th>
<th>Pre-test time/s</th>
<th>Pre-test no. errors</th>
<th>Pre-test combined scaled score</th>
<th>Retest time/s</th>
<th>Retest no. errors</th>
<th>Retest combined scaled score</th>
<th>Retest combined scaled score with time and error component corrections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
<td>9</td>
<td>8</td>
<td>66</td>
<td>2</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>106</td>
<td>8</td>
<td>6</td>
<td>114</td>
<td>9</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>5</td>
<td>9</td>
<td>64</td>
<td>5</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>91</td>
<td>10</td>
<td>8</td>
<td>62</td>
<td>2</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>136</td>
<td>11</td>
<td>2</td>
<td>108</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>65</td>
<td>8</td>
<td>9</td>
<td>58</td>
<td>5</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>83</td>
<td>6</td>
<td>9</td>
<td>79</td>
<td>2</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>89</td>
<td>5</td>
<td>9</td>
<td>62</td>
<td>5</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>7</td>
<td>7</td>
<td>80</td>
<td>3</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>111</td>
<td>10</td>
<td>6</td>
<td>75</td>
<td>3</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>69</td>
<td>6</td>
<td>8</td>
<td>64</td>
<td>6</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>13</td>
<td>84</td>
<td>8</td>
<td>8</td>
<td>65</td>
<td>2</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>84</td>
<td>7</td>
<td>7</td>
<td>65</td>
<td>6</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>145</td>
<td>24</td>
<td>1</td>
<td>133</td>
<td>6</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>99</td>
<td>8</td>
<td>7</td>
<td>80</td>
<td>4</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>17</td>
<td>87</td>
<td>17</td>
<td>5</td>
<td>85</td>
<td>5</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>91</td>
<td>5</td>
<td>9</td>
<td>79</td>
<td>1</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>19</td>
<td>150</td>
<td>11</td>
<td>2</td>
<td>123</td>
<td>9</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>94</td>
<td>13</td>
<td>6</td>
<td>91</td>
<td>5</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>21</td>
<td>91</td>
<td>9</td>
<td>8</td>
<td>90</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
<td>139</td>
<td>36</td>
<td>1</td>
<td>124</td>
<td>0</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>23</td>
<td>94</td>
<td>5</td>
<td>8</td>
<td>76</td>
<td>0</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>
### Table A4.7 continued

<table>
<thead>
<tr>
<th>Child</th>
<th>Pre-test total errors</th>
<th>Pre-test scaled score</th>
<th>Retest total errors</th>
<th>Retest scaled score</th>
<th>Retest corrected scaled score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>6</td>
<td>3</td>
<td>10</td>
<td>8.4</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>2</td>
<td>16</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>7</td>
<td>3</td>
<td>13</td>
<td>12.1</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>6.4</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>8.1</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>8.1</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>8.4</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
<td>5</td>
<td>5</td>
<td>11</td>
<td>9.4</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>8</td>
<td>3</td>
<td>12</td>
<td>10.4</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>6</td>
<td>12</td>
<td>7</td>
<td>5.4</td>
</tr>
<tr>
<td>13</td>
<td>15</td>
<td>6</td>
<td>2</td>
<td>14</td>
<td>13.1</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>7.4</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td>9.1</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
<td>7</td>
<td>5</td>
<td>11</td>
<td>9.4</td>
</tr>
<tr>
<td>17</td>
<td>27</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>8.1</td>
</tr>
<tr>
<td>18</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>12</td>
<td>10.4</td>
</tr>
<tr>
<td>19</td>
<td>16</td>
<td>5</td>
<td>19</td>
<td>4</td>
<td>2.4</td>
</tr>
<tr>
<td>20</td>
<td>22</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>7.4</td>
</tr>
<tr>
<td>21</td>
<td>19</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>8.4</td>
</tr>
<tr>
<td>22</td>
<td>38</td>
<td>1</td>
<td>0</td>
<td>15</td>
<td>13.4</td>
</tr>
<tr>
<td>23</td>
<td>11</td>
<td>8</td>
<td>0</td>
<td>15</td>
<td>13.4</td>
</tr>
</tbody>
</table>
Figure A4.12: Graphs of scaled scores pre-test

These are bar charts and not histograms. For the brief purpose of judging data for parametric testing, this is not important. Equally, it would not be appropriate to create a histogram for discrete data, particularly for a small sample size.
Figure A4.13: Calculations for retest score corrections

Examples of method used to create corrected retest combined scaled scores for Naming, Inhibition and Shift

1. Participant 14 for Naming:
   Retest time scaled score is 12. For child aged 13:08 the retest scaled score inflation is 1.1 (see Table 3.1). This creates a corrected score of 10.9.

   Retest error banding is 11-25. Suggested rule-of-thumb error inflation is one banding, see below. This creates a corrected error band of 6-10.

   A corrected combined scaled score of 7 is obtained from the published table, using corrected contributory scores 10.9 and 6-10 from above.

   (Where necessary, the corrected retest time scaled score is rounded to the nearest whole number to allow use of the combined score table.)

2. Participant 17 for Shift:
   Retest time scaled score is 11. For child aged 12:09 the retest scaled score inflation is 1.4. This creates a corrected score of 9.6.

   Retest error banding is 11-25. Suggested rule-of-thumb error inflation is one banding, see below. This creates a corrected error band of 6-10.

   A corrected combined scaled score of 6 is obtained from the published table, using corrected contributory scores 9.6 and 6-10 from above.

Example of method used to create corrected retest Total Error scaled scores

Participant 8:
Retest Total Error scaled score is 9. For child aged 12:10 the retest scaled score inflation is 0.9. This creates a corrected score of 8.1.

Calculations supporting the test-retest correction for error scores bandings contributing to combined scaled scores for Naming, Inhibition and Shift

The published test-retest increase in Total Error scaled score is:
- 1.6 for the age group >13:00 and
- 0.9 for the age group 11:00 – 12:11.

Hence the mean increase for the two relevant age groups is 1.25.

The error contribution to combined scaled scores is a percentage banding. Using the standard normal distribution, each percentage banding can be turned into a scaled score banding, see Table A4.8. The scaled score band mid-points can then be calculated and used to give a guide as to the size of change in scaled score that corresponds with dropping down one percentage banding, see Table A4.8. They are of the same order of magnitude or bigger than 1.25, the mean Total Error scaled score test-retest increase. Hence moving down one percentage banding is an appropriate retest correction for error.
<table>
<thead>
<tr>
<th>Percentage banding</th>
<th>Scaled score banding</th>
<th>Scaled score band mid-point</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2</td>
<td>&lt;3.82</td>
<td></td>
</tr>
<tr>
<td>For top boundary:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.02 0.98</td>
<td></td>
</tr>
<tr>
<td>Using standard normal distribution tables:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p(z=2.06) = 0.9803$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p(z=-2.06) = 0.0197$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using $z = \frac{X-10}{3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-2.06 = \frac{X-10}{3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X = 3.82$, giving $X &lt; 3.82$ for the inequality.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 – 5</td>
<td>3.82 – 5.20</td>
<td>4.51</td>
</tr>
<tr>
<td>For top boundary:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.055 0.945</td>
<td></td>
</tr>
<tr>
<td>Using standard normal distribution tables:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p(z=1.60) = 0.9452$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p(z=-1.60) = 0.0548$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using $z = \frac{X-10}{3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-1.60 = \frac{X-10}{3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X = 5.20$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 – 10</td>
<td>5.20 – 6.25</td>
<td>5.73</td>
</tr>
<tr>
<td>11 – 25</td>
<td>6.25 – 8.02</td>
<td>7.14</td>
</tr>
<tr>
<td>26 – 50</td>
<td>8.02 – 10.03</td>
<td>9.03</td>
</tr>
<tr>
<td>51 – 75</td>
<td>10.03 – 12.07</td>
<td>11.05</td>
</tr>
<tr>
<td>&gt;75</td>
<td>&gt;12.07</td>
<td></td>
</tr>
</tbody>
</table>

All values shown to 2 decimal places.

* $X$ is used to represent the scaled score variable, which has a mean of 10 and standard deviation of 3.
Table A4.9: Contrast scaled scores for all participants

| Participant Number | Naming vs inhibition | | | Inhibition vs Switch | | |
|-------------------|----------------------|---|---|----------------------|---|
|                   | Pretest | Original retest | Corrected retest | Pretest | Original retest | Corrected retest |
| 1                 | 4       | 10             | 8              | 10      | 15             | 12              |
| 2                 | 7       | 2              | 1              | 8       | 9              | 7               |
| 4                 | 9       | 17             | 13             | 10      | 5              | 7               |
| 5                 | 11      | 19             | 14             | 8       | 13             | 11              |
| 6                 | 8       | 11             | 9              | 2       | 6              | 6               |
| 7                 | 7       | 14             | 11             | 10      | 12             | 10              |
| 8                 | 14      | 7              | 6              | 9       | 12             | 10              |
| 9                 | 11      | 8              | 7              | 10      | 11             | 10              |
| 10                | 8       | 15             | 14             | 9       | 9              | 9               |
| 11                | 13      | 12             | 10             | 5       | 10             | 9               |
| 12                | 7       | 7              | 7              | 10      | 10             | 9               |
| 13                | 10      | 17             | 12             | 8       | 12             | 10              |
| 14                | 11      | 10             | 9              | 10      | 8              | 7               |
| 15                | 9       | 10             | 7              | 1       | 5              | 3               |
| 16                | 7       | 10             | 8              | 9       | 11             | 10              |
| 17                | 9       | 12             | 11             | 6       | 8              | 6               |
| 18                | 9       | 11             | 9              | 10      | 14             | 11              |
| 19                | 8       | 1              | 2              | 3       | 8              | 6               |
| 20                | 6       | 11             | 9              | 8       | 10             | 9               |
| 21                | 5       | 12             | 11             | 11      | 6              | 5               |
| 22                | 14      | 11             | 10             | 1       | 10             | 8               |
| 23                | 11      | 12             | 10             | 8       | 13             | 10              |
### Figure A4.14: Calculations for Wilcoxon matched pairs test

#### Naming combined scaled scores:

<table>
<thead>
<tr>
<th>Child</th>
<th>Pretest</th>
<th>Corrected retest</th>
<th>Difference, D=t1-t2</th>
<th>Rank of difference, D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>7</td>
<td>-4</td>
<td>-13</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>7</td>
<td>-2</td>
<td>-4.5</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>8</td>
<td>-3</td>
<td>-9</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>10</td>
<td>-7</td>
<td>-17</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>5</td>
<td>-2</td>
<td>-4.5</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>10</td>
<td>-3</td>
<td>-9</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>7</td>
<td>-1</td>
<td>-1.5</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>10</td>
<td>-4</td>
<td>-13</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>7</td>
<td>-2</td>
<td>-4.5</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>7</td>
<td>-5</td>
<td>-15</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>8</td>
<td>-2</td>
<td>-4.5</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>21</td>
<td>5</td>
<td>8</td>
<td>-3</td>
<td>-9</td>
</tr>
<tr>
<td>22</td>
<td>4</td>
<td>8</td>
<td>-4</td>
<td>-13</td>
</tr>
<tr>
<td>23</td>
<td>4</td>
<td>10</td>
<td>-6</td>
<td>-16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum negative ranks</th>
<th>Sum positive ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-133.5</td>
<td>19.5</td>
</tr>
<tr>
<td>T = 19.5</td>
<td></td>
</tr>
</tbody>
</table>

N=17, critical value = 24 for 0.5% 1-tailed
### Inhibition combined scaled scores:

<table>
<thead>
<tr>
<th>Child</th>
<th>Pretest</th>
<th>Corrected retest</th>
<th>Difference, (D=t_1 - t_2)</th>
<th>Rank of difference, (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>8</td>
<td>-4</td>
<td>-12</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>9.5</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>12</td>
<td>-5</td>
<td>-14</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>13</td>
<td>-3</td>
<td>-9.5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>10</td>
<td>-3</td>
<td>-9.5</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>6</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>11</td>
<td>-6</td>
<td>-16</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>5.5</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>9</td>
<td>12</td>
<td>-3</td>
<td>-9.5</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>8</td>
<td>-2</td>
<td>-5.5</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>8</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>18</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>6</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
<td>10</td>
<td>-7</td>
<td>-17</td>
</tr>
<tr>
<td>22</td>
<td>11</td>
<td>9</td>
<td>2</td>
<td>5.5</td>
</tr>
<tr>
<td>23</td>
<td>8</td>
<td>10</td>
<td>-2</td>
<td>-5.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum negative ranks</th>
<th>Sum positive ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-102.5</td>
<td>50.5</td>
</tr>
</tbody>
</table>

\(T=50.5\)

\(N=17\), critical value = 42 for 5% 1-tailed
Shift combined scaled scores:

<table>
<thead>
<tr>
<th>Child</th>
<th>Pretest</th>
<th>Corrected retest</th>
<th>Difference, $D_{t1-t2}$</th>
<th>Rank of difference, $D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>11</td>
<td>-3</td>
<td>-16.5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>12</td>
<td>-4</td>
<td>-19</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>5</td>
<td>-3</td>
<td>-16.5</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>10</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>9</td>
<td>-2</td>
<td>-12</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>9</td>
<td>-3</td>
<td>-16.5</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>11</td>
<td>-3</td>
<td>-16.5</td>
</tr>
<tr>
<td>14</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>2</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>9</td>
<td>-2</td>
<td>-12</td>
</tr>
<tr>
<td>17</td>
<td>5</td>
<td>6</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>18</td>
<td>9</td>
<td>10</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>19</td>
<td>2</td>
<td>3</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>20</td>
<td>6</td>
<td>7</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>21</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>8</td>
<td>-7</td>
<td>-20</td>
</tr>
<tr>
<td>23</td>
<td>8</td>
<td>10</td>
<td>-2</td>
<td>-12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum negative ranks</th>
<th>Sum positive ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-171</td>
<td>39</td>
</tr>
</tbody>
</table>

$T=39$

$N=20$, critical value = 52 for 2.5% 1-tailed
### Figure A4.14 continued

**Inhibition-Shift contrast scaled scores:**

<table>
<thead>
<tr>
<th>Child</th>
<th>Pretest</th>
<th>Corrected retest</th>
<th>Difference, D=t1-t2</th>
<th>Rank of difference, D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>12</td>
<td>-2</td>
<td>-8.5</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>11</td>
<td>-3</td>
<td>-12.5</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>6</td>
<td>-4</td>
<td>-15.5</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>10</td>
<td>-1</td>
<td>-3.5</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>9</td>
<td>-4</td>
<td>-15.5</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>9</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>10</td>
<td>-2</td>
<td>-8.5</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>3</td>
<td>-2</td>
<td>-8.5</td>
</tr>
<tr>
<td>16</td>
<td>9</td>
<td>10</td>
<td>-1</td>
<td>-3.5</td>
</tr>
<tr>
<td>17</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>11</td>
<td>-1</td>
<td>-3.5</td>
</tr>
<tr>
<td>19</td>
<td>3</td>
<td>6</td>
<td>-3</td>
<td>-12.5</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>9</td>
<td>-1</td>
<td>-3.5</td>
</tr>
<tr>
<td>21</td>
<td>11</td>
<td>5</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>8</td>
<td>-7</td>
<td>-18</td>
</tr>
<tr>
<td>23</td>
<td>8</td>
<td>10</td>
<td>-2</td>
<td>-8.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum negative ranks</th>
<th>Sum positive ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-122</td>
<td>49</td>
</tr>
</tbody>
</table>

T=49  
N=18, critical value = 47 for 10% 2-tailed
Figure A4.14 continued

<table>
<thead>
<tr>
<th>Child</th>
<th>Pretest</th>
<th>Corrected retest</th>
<th>Difference, (D=t_1-t_2)</th>
<th>Rank of difference, (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>12.4</td>
<td>-6.4</td>
<td>-19</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4.4</td>
<td>-2.4</td>
<td>-12</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>8.4</td>
<td>-0.4</td>
<td>-2</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>14.1</td>
<td>-7.1</td>
<td>-20.5</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>4.4</td>
<td>0.6</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>11.1</td>
<td>-4.1</td>
<td>-17</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>9.1</td>
<td>-1.1</td>
<td>-5</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>8.4</td>
<td>-1.4</td>
<td>-7.5</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>8.4</td>
<td>-3.4</td>
<td>-15</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>8.4</td>
<td>-0.4</td>
<td>-2</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>6.4</td>
<td>-0.4</td>
<td>-2</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>13.1</td>
<td>-7.1</td>
<td>-20.5</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
<td>6.4</td>
<td>2.6</td>
<td>13</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>3.1</td>
<td>-2.1</td>
<td>-11</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>8.4</td>
<td>-1.4</td>
<td>-7.5</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>6.1</td>
<td>-5.1</td>
<td>-18</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>11.4</td>
<td>-1.4</td>
<td>-7.5</td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td>3.4</td>
<td>1.6</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>6.4</td>
<td>-3.4</td>
<td>-15</td>
</tr>
<tr>
<td>21</td>
<td>4</td>
<td>5.4</td>
<td>-1.4</td>
<td>-7.5</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>8.4</td>
<td>-7.4</td>
<td>-22</td>
</tr>
<tr>
<td>23</td>
<td>8</td>
<td>10</td>
<td>-3.4</td>
<td>-15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum negative ranks</th>
<th>Sum positive ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>-226</td>
<td>27</td>
</tr>
</tbody>
</table>

\(T=27\)

N=22, critical value = 47 for 0.5% 1-tailed
1. Pre-study calculations

a) required size of mean scaled score change

Assume mean=10, standard deviation=3.

Use Cohen’s $d = \frac{\text{difference in means}}{\text{standard deviation of first data set}}$.

Use effect size=0.5. This is accepted as a moderate effect size. Röthlisberger et al., (2012) obtained effects sizes of 0.42, 0.43 and 0.59.

Hence required mean score change=0.5x3 = 1.5

b) desirable sample size

For 80% power, cut-off ($\alpha$) of 0.05, 1-tailed and effect size of 0.5

Sample size = $(2.5/\text{Cohen’s d effect size})^2$

Sample size needed=$(2.5/0.5)^2$=25

Using the same parameters in G*power3, sample size needed is 27.

Current sample falls short. So need to be careful with potentially incorrectly rejecting the null hypothesis.

2. Calculations after baseline (pretest) data collected:

a) required size of mean scaled score change

= 0.5xactual standard deviation of first data set

For Naming combined scaled score, required mean score change = 0.5x2.08 = 1.04 (all numbers given to 3 sig. fig.s)

For Inhibition combined scaled score, required mean score change = 0.5x2.42 = 1.21 (all numbers given to 3 sig. fig.s)

For Switch combined scaled score, required mean score change = 0.5x2.67 = 1.33 (all numbers given to 3 sig. fig.s)

For Naming-Inhibition contrast scaled score, required mean score change = 0.5x2.69 = 1.35 (all numbers given to 3 sig.fig.s)

For Inhibition-Switch contrast scaled score, required mean score change = 0.5x3.14 = 1.57 (all numbers given to 3 sig.fig.s)

For Total Error scaled score, required mean score change = 0.5x2.66 = 1.33 (all numbers given to 3 sig. fig.s)
3. Calculations after all data collected

Use Cohen’s $d = \frac{\text{difference in means}}{\text{standard deviation of first data set}}$.

For Naming combined scaled score, $d = \frac{1.86}{2.08} = 0.90$

For Switch combined scaled score, $d = \frac{1.27}{2.67} = 0.48$

For Total Error scaled score, $d = \frac{3.05}{2.66} = 1.14$

Use Standardised response mean = $\frac{\text{difference in means}}{\text{standard deviation of differences}}$.

s.r.m. is also known as $d_z$

For Naming combined scaled score, $\text{s.r.m.} = \frac{1.86}{2.62} = 0.71$

For Switch combined scaled score, $\text{s.r.m.} = \frac{1.27}{2.12} = 0.60$

For Total Error scaled score, $\text{s.r.m.} = \frac{3.05}{3.54} = 0.86$

For comparison, from s.r.m., Cohen’s $d = s.r.m \times \sqrt{2}$. This gives:

For Naming combined scaled score, Cohen’s $d = 1.00$

For Switch combined scaled score, Cohen’s $d = 0.84$

For Total Error scaled score, Cohen’s $d = 1.22$

All numbers given to 3 sig. fig.s

4. Post hoc power calculations, using G*Power 3.1.7:

For sample size 22; $\alpha = 0.05$ (assuming power >90% is ideal, but >80% is acceptable):

Naming: $d_z = s.r.m = 0.71$; power = 0.93 = very acceptable

Shift: $d_z = s.r.m = 0.60$; power = 0.84 = just acceptable

Error: $d_z = s.r.m = 0.86$; power = 0.98 = very acceptable
Figure A4.16: Mean change by initial score level

<table>
<thead>
<tr>
<th>Group</th>
<th>Changes</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low group, n=11</td>
<td>-2, 3, 2, 3, 0, 1, 2, 1, 1, 1, 7</td>
<td>1.7 or if remove ‘outlier’ 1.2</td>
</tr>
<tr>
<td>Medium (i.e. higher) group, n=11</td>
<td>3, 4, -1, 3, -2, 2, -1, 1, 0, -1, 1</td>
<td>0.82</td>
</tr>
</tbody>
</table>