Title: The SCAN-C in testing for auditory processing disorder in a sample of British children

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Acronyms and abbreviations: (FW) filtered words, (AFG) auditory figure-ground, (CW) competing words, (CS) competing sentences, (CCC-2) Children's

Communication Checklist-2, (APD) auditory processing disorder, (PPVT) Peabody Picture Vocabulary Test, (CELF-R) Clinical Evaluation of Language Fundamentals – Revised.

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Abstract

The SCAN-C is a test for auditory processing disorders in children developed in the USA. There are concerns that the SCAN-C may over diagnose auditory processing disorder in UK children. There are also questions concerning the impact of language level and interpretation of SCAN-C results. SCAN-C results from 99 Oxfordshire school children aged 6 to 10 were compared to US-based normative data. Across all age bands, the UK sample scored significantly worse on two subtests: the Filtered Words (FW) and Auditory Figure-Ground (AFG) sections as well as on the Composite Score. Differences in performance were largely due to accent effects. Applying US norms to UK children's performance results in a high rate of over-identification of listening difficulties. However, we show that US norms can be used provided SCAN-C scores for children in the UK are adjusted by adding a constant. Using factor analysis, SCAN-C subtests mapped onto two factors; FW and AFG onto a 'monaural low-redundancy degradation' factor and CW and CS onto a 'binaural separation/competition' factor. Implications for use of the SCAN-C with UK children are discussed.

Introduction

Auditory processing disorder (APD) is defined as a hearing disorder resulting from impaired brain function, in which the primary manifestation is listening difficulties in challenging auditory environments despite having a normal audiogram (ASHA, 1996; ASHA, 2005; British Society of Audiology, 2005). These listening difficulties have also

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been called ‘obscure auditory dysfunction’, ‘central auditory dysfunction’, or ‘central auditory processing disorder’. The listening difficulties are thought to contribute to academic, behavioral, and social difficulties.

The SCAN-C

The SCAN-C (Keith, 2000) is the most widely used screening test for APD in both the US and the UK (Emanuel, 2002; Hind, 2006); although, there are questions of whether US norms are appropriate for use with other populations (Woods et al., 2004). A study assessing an earlier version of the SCAN-C, the SCAN (Keith, 1986), revealed that a group of UK school children scored significantly worse than US norms for most age groups (Marriage et al., 2001). The goal of this study was to examine whether the latest version of the SCAN suffered from the same bias as the original, and if so, how this might be countered.

The SCAN-C is individually administered either in audiometric conditions or in a quiet room to children between ages 5 and 11.11 years. In addition to the previous version of the SCAN for children (Keith, 1986), there is also a version for adults and adolescents above the age of 12, the SCAN-A (Keith, 1994). SCAN-C stimuli are recorded on CD and played over headphones; therefore, the test is easily administered in a range of settings without special equipment. Testing time is around 20 minutes. The SCAN-C provides an overall score as well as scores for the four subtests. The total number of correct responses for each subtest is summed and converted to standardized scores based

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on normative data from US school children organized according to age band. The four subtests are as follows:

- Filtered Words (FW)

The child is asked to repeat monosyllabic words that have been low-pass filtered at 1000 Hz with a roll-off of 32 dB per octave.

- Auditory Figure-Ground (AFG)

The child is asked to repeat monosyllabic words that are presented against a background of multi-talker speech babble (similar to the 'cocktail party' example) at a +8 dB signal to noise ratio.

- Competing Words (CW)

The child hears two monosyllabic words simultaneously, with one word presented to each ear and the child required to repeat each word. An 'ear-advantage' score may be computed for this subtest. Ear advantage scores are thought to reflect hemispheric dominance for language. Abnormal advantage scores may reflect maturational delay or a neurologically based disorder.

- Competing Sentences (CS)

Pairs of sentences unrelated in topic are presented simultaneously to each ear. The child is asked to repeat the sentence presented to one ear while ignoring the other. An 'ear-advantage' score may also be calculated for this subtest.

The SCAN-C is a revised version of the earlier SCAN. The main differences between the SCAN-C and the SCAN are (Keith, 2000):

- Stimuli presented on CD rather than audio tape.
- Addition of a fourth subtest, the Competing Sentences section.
- Revised test instructions, reworded to make them easier for children to understand.
- The Competing Words subtest shortened and revised.
- A new method of calculating the composite standard score giving equal weighting to each subtest.
- Elimination of normative data for 3 and 4 year old children.
- Norms that are more representative of the US population based on US census data.

According to the SCAN-C manual, test-retest reliability for individual subtests is improved over those of the SCAN, now ranging from 0.65 to 0.82 by subtest. SCAN-C subtest scores significantly correlate with equivalent subtests from the SCAN. Like the Competing Words subtest, the newly added Competing Sentences subtest is a dichotic speech task (it involves simultaneous presentation to both ears). Both tests are described as involving 'directed listening'; although, the CW test involves listening with both ears and sequencing the response (i.e. right or left word first), whereas the CS test requires attending to the sentence presented to one ear while ignoring the sentence presented to the other. The SCAN-C manual (Keith, 2000) states that the CS subtest was added to

provide "additional data on how the child uses linguistic cues when interpreting speech" (p. 67).

The SCAN-C also features a change of name, with the word 'screening' being omitted from the title of the SCAN. This seems to suggest the use of the SCAN as a diagnostic instrument in clinical practice (Emanuel, 2002; Hind, 2006), despite some clinicians continuing to assert that the SCAN is only a screening test (Medwetsky, 2002; Bellis, 2003). In addition, the notion of using the SCAN as an assessment tool has been criticized because it does not contain a temporal processing measure (Bellis, 1996). A child may do well on SCAN tests of competing, degraded or dichotically presented speech and still have a problem with speech perception due to poor auditory temporal resolution.

SCAN tests were developed to be given either in a quiet room or audiometric conditions, although the norms were developed from quiet room testing only. One study found that children tended to perform better on the SCAN under audiometric conditions and cautioned interpretation of results obtained in this setting (Emerson et al., 1997). The current study was conducted under 'quiet room' conditions.

Linguistic factors and SCAN performance

The SCAN-C purportedly measures the pre-cognitive, perception stage of auditory processing (Keith, 2000). The SCAN-C manual says that the child is required to repeat

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stimulus words or sentence and that no knowledge of concepts like 'same' or 'different' or understanding at a cognitive level of phonetic differences between speech sounds is required. The test is also designed to avoid cross-modality and cognitive aspects of having a child to point to a picture in response to a word.

However, as Rosen (2005) points out, the perception of phonetic differences does depend on language experience; perception of some speech contrasts is especially difficult for non-native speakers. Any test that uses speech stimuli cannot, therefore be tapping only a perceptual stage of processing and must at least draw on phonological processing, which is shaped by language experience. A deficit in phonological processing is also implicated in dyslexia and specific language impairment (Bishop, 1997). One might also expect that vocabulary and word-retrieval skills would have an impact on performance on the first three SCAN subtests, while semantic, syntactic, and general world knowledge would have an impact on performance for the Competing Sentences Subtest. The requirement for verbal responding, even if only repetition, would seem to involve a possible confound with production skills. Memory and attention probably influence performance on all subtests; although, one might expect their impact to be greatest on the Competing Sentences subtest, as the stimuli are longest in this subtest. It seems problematic that a test designed for auditory processing might be sensitive to language and phonological skills, especially as language and reading problems are thought to commonly co-occur with auditory processing problems (Chermak & Musiek, 1997; Bamiou et al., 2001). Some might argue that poor auditory processing is in fact a causal factor in poor language and reading skills (Tallal, 2000).

Few of the studies that have investigated use of the SCAN have directly examined associations between language or vocabulary scores and SCAN scores. In a large population-based study of school children, The Benton IU project (Watson et al., 2003) found that a 'speech processing factor', which included subtests from the SCAN, was generally not predictive of reading achievement or academic performance. This study focused on a *clinical* population, and although language and auditory problems commonly co-occurred, they did not seem related in terms of severity. Keith et al (1989) examined correlations between language or vocabulary scores and SCAN scores for 155 children referred to a clinic for possible auditory and/or language processing disorders. They found correlations between SCAN scores and vocabulary (as measured by the PPVT) but not between SCAN and other language measures (CELF-R subtests) (Keith et al., 1989). The association between vocabulary and a SCAN score might reflect the positive impact of a higher vocabulary on SCAN performance or may merely reflect the impact of higher general ability on test performance.

In summary, one might logically expect that good language skills would facilitate performance on a linguistic-based auditory processing test like the SCAN. Language problems commonly co-occur with APD, but it is problematic to clarify associations between the two for either research or clinical purposes especially when using linguistic based tests of auditory processing. This study sought to examine the correlation between SCAN-C scores and a parent-completed questionnaire of communication skills, the CCC-2 (Bishop, 2003).

What does the SCAN measure?

Amos & Humes carried out a factor analysis of the three subtests of the 1986 version of the SCAN with 47 children and found that all three subtests loaded onto a single 'speech processing' factor (Amos & Humes, 1998). They suggested that this did not support the use of the SCAN to compare an individual's performance on specific subtests in deciding on further testing or treatment options, as each subtest appeared to be measuring the same thing. They suggested that the most important value of individual subtests was in contributing to the overall composite score, which was after all the most reliable test index. They therefore recommended that clinical decisions should be based on the composite score rather than scores on individual subtests. Reliability data from the SCAN-C manual suggests that the composite is still the most reliable index ($r = 0.82$ for 8 to 11 year-olds), with reliability of individual subtests ranging upwards from 0.65.

Domitz and Schow also investigated the 1986 version of the SCAN as well as other commonly used APD assessments in a series of articles (Schow & Chermak, 1999; Domitz & Schow, 2000; Schow et al., 2000) and suggested a different factor structure. On the basis of the scores of 331 children, they suggested that the SCAN subtests mapped on two factors: Filtered Words (FW) and Auditory Figure Ground (AFG) onto a factor identified as a 'composite monaural low-redundancy degradation factor'; Competing Words onto a 'binaural separation/competition' factor (Domitz & Schow, 2000).

The SCAN-C has an additional subtest to the 1986 version – the Competing Sentences Subtest. One of the tests Domitz and Schow administered as part of a battery in their 2000 article was the Williford Competing Sentences Test (Williford, 1985), which is similar to the Competing Sentences subtest of the SCAN-C. The Williford Competing Sentences Test loaded on to the binaural separation factor, and it might be reasonably expected that the SCAN-C competing sentences subtest might do so also.

The results of Domitz and Schow's work seem to be in conflict with that of Amos and Humes; Amos and Humes discovered one factor, Domitz and Schow discovered two. Of the two factors, loadings for each SCAN subtest were fairly high for both, suggesting that SCAN subtests did contribute to both factors. Amos and Humes used a smaller number of children than Domitz and Schow's studies and this may have contributed to them only finding one factor.

It is of interest to discover what skills the SCAN-C may be tapping; the SCAN-C manual recommends profiling for further testing and treatment based on scores for individual subtests. Factor analysis could help discover if this is valid or not. It is also of interest to clarify the aspects of auditory processing that commonly used assessments might be tapping into. A factor analysis of subtest scores was carried out in this study to determine if the SCAN-C subtests mapped onto single or multiple factors.

Possible cultural bias

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Several studies have found differences in SCAN and SCAN-A scores between the US norms and various other populations including UK school children (Marriage et al., 2001; Sockalingham et al., 2004; Woods et al., 2004). Woods et al. (2004) found that a higher proportion of Latino-American children scored in the borderline range than might be expected compared to Anglo-American children. However, when responses were rescored to accept variations common in Latino-American children's responses, this difference was eliminated.

Marriage et al (2001) also found their sample of 133 UK children scored significantly worse across most age bands when compared to US norms. They derived interim norms for use in the UK and recommended that test material be re-recorded with a UK English speaker, substituting high error-rate words and collecting appropriate norms. However, as Marriage et al concluded that accent affected children's performance, one might expect that regional variations in accent around the UK might also affect performance, despite re-recording with a UK English speaker.

This study was conducted to find out if the SCAN-C has similar problems to the SCAN as described by Marriage et al, and if so, to discover in what way patterns of performance of UK children differed from those of US children. Additional questions of interest are the factor structure of the SCAN-C and how SCAN-C scores relate to a measure of children's communication.

Method

Subjects

Primary school children aged 6.0 to 10.11 from six different primary schools in Oxfordshire were invited to participate in the study. Out of those children for whom parental consent was received, exclusion criteria were as follows:

- Hearing thresholds greater than 25 dB at all frequencies within the range 250 Hz to 8000 Hz on screening audiometry.
- Asymmetric audiogram.
- Non-response to SCAN-C practice items.
- Non-completion of SCAN-C.
- Aged below 6 years or over 10 years.

Ninety nine children were included in the study (50 males, 49 females). Power analysis suggested that a sample of at least 17 children per age band would be required to detect a difference of 6 units with a power of 80% using a *t*-test, based on published standard deviations for US norms. This minimum number of participants was exceeded for each age band.

Ethnic origin based on parental report was divided into five categories: White (89.9%), Black (1%), Asian (2%), Chinese (2%), and Mixed (5.1%). According to the 2001

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census, 92.1% of the UK population is white

(<http://www.statistics.gov.uk/census2001/profiles/UK-A.asp>).

Post codes were obtained for every participant. Each postcode was classified according to an 'index of multiple deprivation' (<http://neighbourhood.statistics.gov.uk/dissemination/>).

This index ranks geographical areas in England according to a combination of several indices including income, employment, education, housing, health, and crime. Areas are ranked from lowest to highest, with lower scores reflecting higher levels of deprivation.

The most deprived area has a score of 1 and the least deprived a score of 32,482. For this sample, the mean index of multiple deprivation was 23,414 (*sd* 7,256), with a range from 4,511 to 32,412. While the sample is skewed toward more affluent neighbourhoods, poorer neighbourhoods are represented.

If English was spoken as a second language, this was noted. The same examiner carried out testing for every child after having completed training in administration and scoring.

Apparatus

Testing was conducted in a sound dampened mobile clinical testing unit in the rear of a vehicle parked on school grounds. Hearing screenings were carried out with a Micro Audiometrics Corp DSP screening audiometer with TDH-39P headphones. The SCAN-C was administered using a Dell Latitude notebook computer via Sennheiser HD600 stereo headphones.

The Children's Communication Checklist, second edition (Bishop, 2003) (CCC-2) was given to parents to complete and was returned for 81 children. The CCC2 is a parent-completed questionnaire that can be used to screen for language impairment, to identify pragmatic impairments in children with communication problems and to identify children as candidates for further assessment for an autistic spectrum disorder. The CCC2 provides norm-referenced scores for children aged 4 to 16 over ten language (eg syntax, semantics) and pragmatic (eg inappropriate initiation, interests) subscales as well as providing an overall index of communicative competence.

The CCC-2 was administered in order to confirm that the sample was typical in terms of communication ability and to gain an indication of the children's communication level for comparison with SCAN-C scores.

Procedure

The SCAN-C was administered and scored as described in the SCAN-C manual. The test begins with a 1000Hz calibration tone to allow adjustment of presentation level. Recorded instructions and practice items begin each subtest. Each test item is preceded by the words 'Say the word'. At the start of testing, the presentation volume was adjusted to a comfortable level for each participant.

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Responses to test items were scored correct if the response was either an imitation of the US English form or the British English pronunciation of the same word. Substitutions (e.g. *end* for *and*) or omissions of the target word were scored incorrect. Stable errors of articulation were scored correct.

Results

Figures 1 to 5 show mean raw scores for each SCAN-C subtest and composite score for UK children compared to US children. Standard deviations were not available for US composite scores. Variances were not significantly different for any measures between US and UK groups based on single sided probability that variances are equal, an *F* test. The variance of the UK group's composite score was therefore used as an estimate of the variance of the US group's composite score.

For all age groups and all scores, UK children tended to score worse than US children, with the exception of the Competing Sentences subtest, where 7 and 8 year old UK children tended to score slightly better than their US peers. Differences in UK/US scores were generally highly significant for Filtered Words, Auditory Figure Ground subtests and the Composite Score. Interestingly, on the two dichotic tasks, Competing Words and Competing Sentences, UK and US children were more similar.

Numbers of clinical cases

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Applying US norms to the UK sample would yield a higher than expected number of clinical cases. For 'Borderline' cases, the recommended cut-off in the SCAN-C manual is a composite standard score from 70 to 84, or 12% of cases. Applying US norms to the UK sample resulted in 22% to 40% of UK children falling within the borderline category, depending on the subtest (Table 1).

For 'Disordered' cases, the recommended cut-off is a composite standard score of 69 or less, or about 2% of cases. Applying these norms to the UK sample resulted in 5% to 10% of children being within the disordered category (Table 2).

Measures of dispersion were not significantly different for the two groups and scores were normally distributed. One could therefore adjust scores by adding the difference between UK and US children's raw scores to the UK children's raw score, then calculating an adjusted standard score using the US norms. Where significant differences exist, these are shown by subtest and age group in Table 3. These numbers should be added to UK children's raw subtest scores prior to comparison with US SCAN-C norms.

An alternative method of compensating would be to accept common alternative responses of UK children. However, an error analysis (described below) found that while there are high error rates for some problematic items, alternative responses are not always consistent. Additionally, in terms of ease of scoring and administration, it seems simpler to make an adjustment to the raw score at the end of each subtest rather than use lists of acceptable alternative responses for several items in each subtest.

Error analysis

Patterns of errors were examined for FW and AFG subtests, as performance of UK children differed significantly from that of US children on these two subtests. Items with error rates over 50% are shown in table 4. The most common alternative responses (those that occur over 20% of the time) for each item are also shown. Some errors seem to be due to accent misinterpretation (for example ‘on’ for ‘own’ or ‘dead’ for ‘did’) or word familiarity (for example ‘sled’), in which case UK accent homophones of words or non-words are substituted. Error patterns also support Marriage et al’s (2001) conclusion in reference to the SCAN that these tasks are not purely imitative. Rather, listeners seem to be drawing on speech recognition mechanisms to identify target words. The mismatch of US-accented input to UK listener’s lexical representations leads to a greater processing load and higher error rates for UK children.

Children’s Communication Checklist (CCC-2)

The mean General Communication Index score from the CCC-2 for the sample was 81.5 (*sd* 18.7). This suggests that the sample as whole is typical in terms of communication skill; an average score is 82. There was no correlation between CCC-2 scores and SCAN-C scores. The highest correlations were with Speech and Syntax scales of the CCC-2 with the SCAN-C CS subtest ($r = .264$ and $.224$) and CCC-2 Syntax and Nonverbal scales with

the SCAN-C composite score ($r = .262$ and $.235$), although none of these were significant following a Bonferroni correction for multiple comparisons.

Factor analysis

Principal components analysis of pooled standard scores was carried out giving a sample size of $n = 99$. The KMO statistic for adequacy of sample size was 0.7, on the lower end of the 'good' range (Field, 2005). The KMO statistic for individual variables was also satisfactory. An initial analysis yielded one factor with an eigenvalue greater than 1. However, there were less than 30 variables and communalities after extraction less than 0.71 therefore, selecting factors with eigenvalues over 1 was not an accurate criterion (Field, 2005). A more satisfactory solution was provided with Jolliffe's criterion of including factors with eigenvalues of 0.7. This yielded two factors; the first factor had an eigenvalue of 2.01 and the second factor 0.82. The first factor accounted for 50.1% of variance and the second for 20.4% of variance, accounting for a total of 70.5% of the variance. A two factor solution is consistent with the findings of Domitz and Schow (Domitz & Schow, 2000).

These two factors were significantly correlated ($r = -0.34$); therefore, an oblique rotation was applied in order to clarify how the four subtests map onto the two factors. In any case, the solution using orthogonal rotation was similar, with loadings within 0.08 of the oblique solution.

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After rotation, the unique contribution connecting each variable to each factor is detailed in the pattern matrix in Table 5. Contributions less than 0.4 are not shown. FW and AFG clearly contribute most strongly to the first factor, which seems in line with Domitz and Schow's 'composite monaural low-redundancy degradation' factor. CW and CS map clearly onto the second 'binaural separation/competition' factor.

The communality indexes in Table 6 suggest that a high degree of variance within the SCAN-C test is to be found within these two factors, although there is still some variance unexplained. This might be accounted for by an auditory temporal processing variable, language skill, attention, motivation, or general ability.

Discussion

The SCAN-C is readily available commercially and is easy to administer in a range of settings. It has a high quality CD recording of stimuli, a detailed manual that describes administration, scoring and interpretation as well as reliability and population-based normative data. These factors help make the SCAN-C an attractive choice for clinicians to use in screening for and diagnosing listening difficulties in children.

However, there are limitations in using the SCAN-C of which users should be aware. The sample of UK children described in this article scored significantly worse than the US norms for the FW, AFG, and Composite sections. The difference on these three scales was close to one standard deviation. An error analysis suggested that accent and word

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familiarity effects might be responsible for UK children's high error rates on some items. This problem might be compensated for by adjusting UK children's raw scores before conversion to standard scores using US norms. As accent effects seem to have a significant effect on performance, re-recording the SCAN-C with a British accented speaker might not be an ideal solution because one would expect regional variations in accent to impact performance as well. Any test that uses linguistic stimuli is likely to be susceptible to differences in language familiarity. At a minimum, non-linguistic tests of auditory processing should be used to supplement linguistically-based tests such as the SCAN.

For most age bands, differences between the UK sample and US norms were *not* significant for the two dichotic tests CW and CS. It is interesting that differences should be so marked for the FW and AFG subtests yet not so for CW and CS. Factor analysis suggested that FW and AFG contributed to a 'composite monaural low-redundancy degradation' factor, while CW and CS mapped onto a second 'binaural separation/competition' factor. Word familiarity and accent effects may impact more severely on perception of low redundancy/degraded speech, while impact of accent is less severe on tests of binaural separation/competition, where a different skill (directed listening) is drawn upon.

For a non-clinical sample of typical school children, there was generally no association between communicative competence and SCAN-C scores. The weak associations that were detected might be the result of the impact of higher general ability (which was not

assessed) on communicative skill and test performance. While there may be no association for a typical sample, this may not be the case for a clinical sample. While there were culturally-related language effects, the majority of children in this sample had sufficient language skills for language level not to be an issue for SCAN-C performance. However, test users should be aware of interpreting SCAN-C results for children with low language skills, whether due to English as a second language or language impairment.

The two-factor structure of the SCAN-C does not support interpretation of discrepantly low individual subtest results; the SCAN-C seems to assess two auditory processing skills, FW and AFG monaural perception of low-redundancy/degraded speech and CW and CS binaural separation/competition. This study does not offer any evidence for how these two skills play out in terms of functional listening behaviors; although, they both probably relate to listening in challenging auditory environments, first, listening in noisy reverberant rooms where the acoustic quality of speech is degraded and second, attending to one speaker's signal against competing signals. With any pattern of results, one should consider whether the results reflect actual listening difficulties experienced in a natural setting and if the test results might reflect a disorder of language, memory, or attention.

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References

- Amos N.E. & Humes L.E. 1998. SCAN test-retest reliability for first- and third-grade children. *J Speech Lang Hear Res*, 41, 834-845.
- ASHA 1996. Central auditory processing: Current status of research and implications for clinical practice. *Am J Audiol*, 5, 41-54.
- ASHA 2005. (Central) auditory processing disorders [Internet], American Speech-Language-Hearing Association, Available from
<<http://www.asha.org/members/deskref-journals/deskref/default>> [Accessed 4 January 2006].
- Bamiou D.E., Musiek F.E. & Luxon L.M. 2001. Aetiology and clinical presentations of auditory processing disorders - a review. *Arch Dis Child*, 85, 361-365.
- Bellis T.J. 1996. *Assessment and management of central auditory processing disorders in the educational setting: from science to practice*. San Diego: Singular Publishing Group.
- Bellis T.J. 2003. *Assessment and management of central auditory processing disorders in the educational setting: From science to practice*. Clifton Park, NY: Delmar Learning.
- Bishop, D. V. M. (1997). *Uncommon understanding*. Hove: Psychology Press.
- Bishop D.V.M. 2003. *Children's Communication Checklist (CCC-2)*. London: Harcourt Assessment.
- British Society of Audiology 2005. Working definition of APD [Internet], British Society of Audiology, Available from

- <<http://www.thebsa.org.uk/apd/Home.htm#working%20def;2005>> [Accessed 12 March 2006].
- Chermak G.D. & Musiek F.E. 1997. *Central auditory processing disorders*. San Diego: Singular.
- Domitz D.M. & Schow R.L. 2000. A new CAPD battery-multiple auditory processing assessment: Factor analysis and comparisons with SCAN. *Am J Audiol*, 9, 1-11.
- Emanuel D.C. 2002. The auditory processing battery: Survey of common practices. *J Am Acad Audiol*, 13, 93-117.
- Emerson M.F., Crandall K.K., Seikel J.A. & Chermak G.D. 1997. Observations on the use of SCAN to identify children at risk for central auditory processing disorder. *Language, Speech and Hearing Services in Schools*, 28, 43-49.
- Field A. 2005. *Discovering statistics using SPSS*. London: Sage.
- Hind S. 2006. Survey of care pathway for auditory processing disorder. *Audiological Medicine*, 4.
- Keith R.W. (ed.) 1986. *SCAN: A Screening Test for Auditory Processing Disorders in Children*. San Antonio: Psychological Corporation.
- Keith R.W. (ed.) 1994. *SCAN - A: A Test for Auditory Processing Disorders in Adolescence and Adults*. San Antonio: Psychological Corporation.
- Keith R.W. 2000. Development and standardization of SCAN-C test for auditory processing disorders in children. *J Am Acad Audiol*, 11, 438-445.
- Keith R.W. (ed.) 2000. *SCAN-C Test for Auditory Processing Disorders in Children - Revised*. San Antonio: Psychological Corporation.

DAWES The SCAN-C and British children

- Keith R.W., Rudy J., Donahue P.A. & Katbamna B. 1989. Comparison of SCAN results with other auditory and language measures in a clinical population. *Ear Hear*, 10, 382-386.
- Marriage J., King J., Briggs J. & Lutman M.E. 2001. The reliability of the SCAN test: Results from a primary school population in the UK. *Br J Audiol*, 35, 199-208.
- Medwetsky L. 2002. Central auditory processing testing: A battery approach. In: J. Katz (ed.) *Handbook of Clinical Audiology*. Philadelphia: Lippincott, Williams & Wilkins.
- Rosen, S. (2005). "A riddle wrapped in a mystery inside an enigma": Defining central auditory processing disorder. *American Journal of Audiology*, 14, 139-142.
- Schow R.L. & Chermak G.D. 1999. Implications from factor analysis for central auditory processing disorders. *Am J Audiol*, 8, 1-6.
- Schow R.L., Chermak G.D. & Berent M. 2000. Central auditory processes and test measures: ASHA 1996 revisited. *Am J Audiol*, 9, 1-6.
- Sockalingham R., Murrison R., Cole D., James S., Morin S., et al. 2004. Comparing SCAN-A scores between speakers of standard Australian english and American english: A preliminary study. *Aust N Z J Audiol*, 26, 110-115.
- Tallal P. 2000. Experimental studies of language learning impairments: From research to remediation. In: D.V.M. Bishop & L.B. Leonard (eds.) *Speech and language impairments in children*. East Sussex: Psychology Press.
- Watson C.S., Kidd G.R., Horner D.G., Connell P.J., Lowther A., et al. 2003. Sensory, cognitive, and linguistic factors in the early academic performance of elementary school children: the Benton-IU Project. *J Learn Disabil*, 36, 165-197.

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Williford J.A. 1985. Assessment of central auditory disorders in children. *In*: M.L.

Pinhiero & J.M. Burleigh (eds.) *Assessment of central auditory dysfunction:*

Foundations and clinical correlates. Los Angeles: Williams & Wilkins, pp. 239-259.

Woods A.G., Pena E.D. & Martin F.N. 2004. Exploring possible sociocultural bias on the SCAN-C. *Am J Audiol*, 13, 173-184.

**Table 1. Numbers of
‘Borderline’ cases identified
verses expected**

Age group (<i>N</i>)	Number of borderline cases	Expected number (12% of cases)
6 (18)	4 (22%)	2.2
7 (20)	6 (30%)	2.4
8 (20)	5 (25%)	2.4
9 (20)	8 (40%)	2.4
10 (21)	6 (29%)	2.5

Table 2. Numbers of ‘Disordered’ cases identified verses expected

Age group (N)	Number of disordered cases	Expected number (2% of cases)
6 (18)	1 (6%)	0.36
7 (20)	1 (5%)	0.4
8 (20)	2 (10%)	0.4
9 (20)	2 (10%)	0.4
10 (21)	1 (5%)	0.42

Table 3. Differences* in average raw score between UK and US children to be added to UK children's raw scores prior to comparison with US norms

Age group	<u>Filtered Words</u>	<u>Auditory Figure Ground</u>	<u>Competing Words</u>	<u>Competing Sentences</u>
10	3.2	2.7		
9	5	3		1.7
8	5.7	2.9	4.4	
7	6.8	5		
6	4.4	3.8		

* Difference scores are only shown where significant differences between UK and US children's performance exist.

Table 4. Items with error rates over 50% in the FW and AFG subtests

Filtered Word Subtest (right ear)		
White	56%	Quite 70%
Did	53%	Bib 26% Dead 21%
Need	64%	Mean 30%
Own	89%	On 88%
Find	50%	Fine 56%
Ship	56%	No consistent alternative response
Filtered Word Subtest (left ear)		
Grew	67%	Rew 25% New 21%
Great	67%	Rate 33%
Such	83%	No consistent alternative response
Hit	94%	Hip 71%
Sing	64%	Thing 87%
Auditory Figure Ground Subtest (right ear)		
End	56%	And 60%
Coat	78%	Toke 88%
Thick	53%	Thing 37% Think 42%

DAWES The SCAN-C and British children

Got 53% God 47%

Auditory Figure Ground Subtest (left ear)

His 64% Hills 48% Is 35%

Drop 67% Brock 25%

Sled 86% Slim 35%

Frog 56% From 80%

Bus 50% Muss 50% Must 39%

Fat 56% Thank 25%

**Table 5. Pattern matrix:
Unique contribution by each
variable to each factor**

Subtest	Factor	
	1	2
FW	0.948	
AFG	0.571	
CW	0.413	-0.562
CS		-0.958

**Table 6. Structure matrix:
Contribution by each variable to total
SCAN-C variance with shared
variance taken into account.**

Subtest	Communalities after extraction
FW	0.821
AFG	0.497
CW	0.643
CS	0.861

Student's *t*-test comparing US/UK differences: * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$

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Comparisons of Composite Scores were made on the basis of the assumption of equal variances