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Identifying barriers and facilitators of hearing protection use in early-career musicians: a basis for designing interventions to promote uptake and sustained use

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Abstract

Objective: The current study aimed to: i) determine the patterns of hearing protection device (HPD) use in early-career musicians, ii) identify barriers to and facilitators of HPD use, and iii) use the Behaviour Change Wheel (BCW) to develop an intervention to increase uptake and sustained use of HPDs.

Design: A mixed-methods approach using questionnaires and semi-structured interviews.

Study sample: Eighty early-career musicians (age range = 18–26 years; women n = 39), across all categories of musical instrument.

Results: 42.5% percent of participants reported using HPDs at least once a week, 35% less than once a week, and 22.5% reported never using HPDs for music-related activities. Six barriers and four facilitators of HPD use were identified. Barriers include the impact of HPDs on listening to music and performing, and a lack of concern about noise exposure. Barriers/facilitators were mapped onto the Theoretical Domains Framework. Following the systematic process of the BCW, our proposed intervention strategies are based on ‘Environmental Restructuring’, such as providing prompts to increase awareness of noisy settings, and ‘Persuasion/Modelling’, such as providing credible role models.

Conclusions: For the first time, the present study demonstrates the use of the BCW for designing interventions in the context of hearing conservation.

Introduction

Musicians are at risk of hearing loss and tinnitus due to prolonged exposure to noise on a regular basis (Greasley et al. 2018; Jansen et al. 2009; Sataloff 1991; Schink et al. 2014; Schmidt, Paarup, and Bælum 2019; Zhao et al. 2010). Between 37% and 58% of classical musicians, and 46% and 49% of rock/pop musicians, have hearing loss (for a review see Zhao et al. 2010), compared to approximately 17% of the general population in the UK (Action on Hearing Loss 2015). Additionally, 51% of musicians report experiencing tinnitus (Jansen et al. 2009), compared with approximately 13% of the general population in the UK (Genitsaridi et al. 2019). Despite the increased risk of noise-induced hearing problems, a Finnish survey of professional classical musicians found that only 6% reported consistent use of hearing protection devices (HPDs) (Lautilen 2005). More recently, a UK survey found that 66.5% of professional musicians reported having used HPDs at some point during their careers (Greasley et al. 2018), but it is unclear how regularly musicians use HPDs, and there is room for further improvement in terms of uptake. Common reasons for non-use of HPDs reported by musicians are the detrimental impact of HPDs on music perception and performance, issues relating to comfort and fit, and the belief that HPDs are not needed (Beach and O’Brien 2017; Callahan et al. 2011; Chesky et al. 2009b; Laitinen 2005; Laitinen and Poulsen 2008; Matei et al. 2018; O’Brien, Driscoll, and Ackermann 2015; O’Brien, Ackermann, and Driscoll 2014; Patel 2008; Zander, Spahn, and Richter 2008). Musicians are also more likely to use HPDs if they have an existing hearing problem (Greasley et al. 2018; Laitinen 2005; Laitinen and Poulsen 2008; O’Brien, Ackermann, and Driscoll 2014).

The Control of Noise at Work Regulations (2005), which are applicable to the music and entertainment sectors (Health and Safety Executive 2008), set out the minimum requirements for UK employers to mitigate the risk of hearing damage for their employees (i.e. by reducing noise levels or providing HPDs).
These regulations do not apply to music students, however, as they are not classed as employees (Skeppear et al. 2020). Yet music students may be particularly vulnerable to hearing damage as they progress through a period of intensive musical training and exposure, including personal practice, rehearsals and performances that are independent of their timetabled course of study (Phillips and Mace 2008; Tufts and Skoe 2018; Washnik, Phillips, and Teglas 2016). It has also been proposed that sound levels produced by student ensembles may be higher than professional ensembles because their technical skills are less well developed (Health and Safety Executive 2008). Additionally, many student musicians go on to – or concurrently – work as freelance/self-employed musicians, who are required to manage the risks to themselves under the Control of Noise at Work Regulations (2005). Accordingly, interventions to promote self-responsibility for protecting hearing, and to establish life-long hearing protection habits, are particularly vital in the early stages of musicians’ careers.

Several interventions have been developed to improve the uptake and sustained use of hearing protection by musicians. For example, the ‘Adopt-A-Band’ programme (Etymotic Research) provides high-fidelity musicians’ earplugs and educational resources for those who wish to promote hearing loss prevention behaviours in young musicians. However, this programme has produced mixed findings in terms of HPD uptake (Auchter and Le Prell 2014; Wilson and Ennis 2016). Other education-based programmes have similarly low levels of evidence to support their efficacy or long-term effectiveness for increasing HPD use by musicians (e.g. Chesky 2006; Hansford 2011; Wright-Reid and Holland 2008). The ‘Sound Practice’ project implemented in eight Australian professional orchestras was effective at increasing HPD use, in particular those orchestras that incorporated numerous hearing conservation strategies, such as the provision of custom-moulded musicians’ earplugs, compulsory annual audiological assessments, weekly risk assessments for each member of the orchestra, and compulsory annual education sessions (O’Brien, Driscoll, and Ackermann 2015, 2012; O’Brien, Ackermann, and Driscoll 2014). However, it is not clear which of these strategies – or combination of strategies – led to increased HPD use, nor what the evidence base is for each of these different strategies. It may not be practical or affordable for all orchestras and musical institutions to implement such an extensive range of strategies. It is also unknown whether these intervention strategies would have the same efficacy for early-career musicians.

It is notable that interventions to date have focussed primarily on education and environmental restructuring (i.e. changing the physical environment by providing access to HPDs), with limited success. Therefore it would be useful to explore whether other potential intervention approaches, namely, persuasion, incentivisation, coercion, training, enablement, modelling, or restriction (Michie, van Stralen, and West 2011) may increase HPD uptake and adherence. Moreover, it is not clear how previous interventions were developed; it would be beneficial to use a validated behaviour change model to provide a framework for intervention design, given that evidence suggests that theory-based interventions produce better health outcomes than those that are not (Borrelli 2011; Glanz and Bishop 2010; Heath, Cooke, and Cameron 2015).

The Behaviour Change Wheel (BCW) is a synthesis of 19 frameworks of behaviour change. The BCW provides a systematic and evidence-based approach to identifying what needs to change within a specific target behaviour, and can be used to design and implement interventions (Michie, Atkins, and West 2014, Michie, van Stralen, and West 2011). At the core of the BCW is the Capability, Opportunity and Motivation model of Behaviour (COM-B) comprising six components that drive behaviour: physical capability (e.g. strength, skills, stamina), psychological capability (e.g. knowledge, cognition), physical opportunity (e.g. cost, resources, physical access), social opportunity (e.g. cultural norms, stigma, personal relationships), reflective motivation (e.g. conscious planning and evaluation of beliefs) and automatic motivation (e.g. impulses, desires, reflex responses). The COM-B model is integral to understanding the barriers to and facilitators of the target behaviour, with subsequent steps of the BCW (e.g. identifying intervention functions and behaviour change techniques) implemented to develop behavioural interventions. The BCW has been used in a variety of different contexts for effecting behaviour change, such as smoking cessation (Fulton et al. 2016), medication adherence (Jackson et al. 2014), and promoting physical activity (Webb, Foster, and Poulter 2016).

In the context of hearing health, the BCW has been utilised for various purposes, including designing and implementing interventions to improve the use of hearing aids (Barker, De Lusignan, and Cooke 2018, Barker, Atkins, and de Lusignan 2016; Ismail et al., 2020), documenting the support-seeking experiences of adults with hearing loss (Rolfe and Gardner 2016), developing and evaluating technological interventions to assist people with hearing loss (Maidment et al. 2020b, 2020a, Maidment, Ali, and Ferguson 2019) and the families of those with hearing loss (Nickbakht et al. 2020), and improving the implementation of family-centred care in adult audiology services (Ekberg, Schuetz, Timmer, and Hickson 2020; Timmer, Schuetz, and Hickson 2020). However, the BCW has not yet been applied in the context of hearing conservation. Therefore, the aims of the study presented here were to: i) determine the patterns of HPD use in a large sample ($n = 80$) of early-career musicians, ii) identify the main barriers to and facilitators of HPD use, and iii) use the systematic approach of the BCW to develop intervention strategies to increase uptake and sustained use of HPDs for future evaluation of effectiveness.

**Methods**

**Design**

We conducted a mixed-methods study using questionnaires to quantify HPD use in early-career musicians, and semi-structured interviews to gather their thoughts and opinions about hearing loss and the use of HPDs in order to identify the key barriers and facilitators. In accordance with the Standards for Reporting Qualitative Research (O’Brien et al. 2014), further details regarding the research design and methods for the qualitative aspect of this study can be found in the Supplementary Materials (S1). All data collection was conducted by author SC.

The systematic process of the BCW for intervention design is completed in three stages, with eight steps in total (Michie, Atkins, and West 2014). Stage 1 involves ‘Understanding the behaviour,’ which includes:

- **Step 1** - Defining the problem in behavioural terms,
- **Step 2** - Selecting the target behaviour,
- **Step 3** - Specifying the target behaviour, and
- **Step 4** - Identifying what needs to change; i.e. COM-B model.
Stage 2 involves 'Identifying intervention options', which includes:
- Step 5 - Identifying intervention functions, and
- Step 6 - Identifying policy categories.

Stage 3 involves 'Identifying content and implementation options', which includes:
- Step 7 - Identifying behaviour change techniques (BCTs), and
- Step 8 - Identifying mode of delivery.

For simplicity, we only report outputs from steps 4, 5, and 7, but our full work through of BCW process is documented in the Supplementary Materials (S2).

In brief, the barriers and facilitators from the semi-structured interviews were organised according to the Theoretical Domains Framework (TDF; Cane, O’Connor, and Michie 2012; Michie et al. 2005), which is used to expand on the COM-B model to provide a more detailed understanding of behaviours (Step 4).

We then selected intervention functions that were likely to be effective in evoking HPD use (Step 5). There are nine different intervention functions that represent the overarching means of changing behaviour: Education, Persuasion, Incentivisation, Coercion, Training, Restraint, Environmental restructuring, Modelling and Enablement (Abraham et al. 2009; Michie, van Stralen, and West 2011). Each component of COM-B/TDF is specifically tied to a number of these different intervention functions, as determined by a group of experts in a consensus exercise (Michie, van Stralen, and West 2011). To assist with selecting the most appropriate intervention functions, we employed the APEASE criteria: Affordability, Practicability, Effectiveness/cost-effectiveness, Acceptability, Side-effects/safety and Equity (Michie, Atkins, and West 2014).

Having selected a suitable intervention function, we then identified suitable BCTs (Step 7). BCTs represent the active ingredients or mechanisms underlying the intervention to bring about change. A taxonomy of 93 BCTs has been developed, clustered into 16 groups (e.g., shaping knowledge, antecedents); BCT Taxonomy v1 (BCTTv1; Michie et al. 2013). Each intervention function is linked to a range of possible BCTs, which can be narrowed down according to their frequency of use in previous intervention designs (Most frequent vs. Less frequent) and using the APEASE criteria. Once we had selected the most suitable BCTs, we then drafted intervention strategies for improving HPD use, describing how these BCTs could be delivered.

**Participants**

Eighty participants (age range = 18-26 years; women n = 39) were recruited from the Royal Northern College of Music and the University of Manchester. They were either students taking performance-based bachelor’s or master’s-level music degree courses or had graduated from their degree courses less than a year earlier, so all could be deemed “early-career” musicians. All categories of musical instrument were represented: strings (n = 23), wind (n = 6), brass (n = 13), keyboards (n = 15), percussion (n = 1), voice (n = 18), and contemporary (e.g. amplified electric guitar/bass guitar/keyboards; n = 4). Participants had an average of 13.3 years of musical experience (range = 8-20 years), started playing music at an average age of 7 years (range = 2-14 years), and were engaging in personal practice for an average of 15 hours per week (range = 1-36 hours) and group rehearsals/performances for an average of 6 hours per week (range = 0-40 hours).

As part of the Royal Northern College of Music’s strategy to promote healthy hearing behaviour, all students are required to attend a health and safety lecture on noise-induced hearing loss and its prevention, and are provided with high-fidelity non-custom musicians’ earplugs. This hearing conservation strategy is conducted independently of the current study.

**Procedure**

**HPD use questionnaire**

Participants were asked to complete a short questionnaire regarding HPD use patterns. Participants were asked “How often in a typical week do you use hearing protection?” and provided a written response. Participants were also asked to indicate how often they use HPD for a range of typical music-related activities, including “Personal practice”, “Group rehearsals”, “Performances”, “Attending performances as part of their course”, “Teaching” (e.g. providing lessons), and “Recreational activities” (e.g. attending amplified concerts and nightclubs), with the choice of responses “Never”, “Seldom”, “Sometimes”, “Often” or “Always”.

Participants who indicated no use of HPDs in a typical week and “Never” for all the music activities were considered non-users of HPDs. Participants who indicated no use of HPDs in a typical week but indicated at least some use of HPDs for the music-related activities were deemed as using HPD less than once a week (i.e. occasional users). Participants who provided a response ≥1 for the use of HPDs in a typical week and indicated at least some use of HPDs for the music related activities were deemed as using HPDs at least once a week (i.e. regular users).

Participants were also asked to indicate what type of HPD they most commonly use from the choice of “Single-use soft earplugs”, “Reusable non-custom musicians’ earplugs”, “Custom-moulded musicians’ earplugs” or “Other”. Participants who indicated “Other” were asked to specify the type of HPD that they use most often.

**Semi-structured interviews**

All participants took part in a semi-structured interview based around the following questions:

- “What are your thoughts about hearing loss as a musician?”
- “Is hearing loss something that you or your colleagues are worried about?”
- “What are your thoughts about hearing protection as a musician?”
- “Why do you use or not use hearing protection?”

Participants were encouraged to provide as much detail as possible and were given the opportunity to add any additional thoughts, opinions or comments relating to the topic. Interviews ranged from 2 to 9 minutes in length and were recorded for later transcription.

Questionnaires and interviews were conducted at the University of Manchester in a single face-to-face testing session as part of a wider investigation into hearing health in musicians (Couth et al. 2020).

The study was approved by the University of Manchester Research Ethics Committee in accordance with the Declaration of Helsinki 2013. All participants provided informed consent.
Analysis

Descriptive statistics (percentages) were used to provide an overview of the basic patterns of HPD use amongst early-career musicians, including frequency of HPD use (e.g. at least once a week), frequency of HPD use for different activities (e.g. personal practice), and the type of HPD most commonly used (e.g. custom-moulded).

Each interview was transcribed verbatim and imported into NVivo (version 11; QSR International). Authors SC and ML coded the interview transcripts independently using an inductive approach to generate themes that were strongly linked to the original data (i.e. data-driven) and reflective of the entire data set (Braun and Clarke 2006). These themes are the main overarching barriers and facilitators of HPD uptake and sustained use. Themes were then mapped directly to the relevant TDF domains based on the description of each domain (Michie, Atkins, and West 2014). The two coding authors compared codes/themes and their mapping to the TDF, and discussed discrepancies with author CA to reach a consensus. The final intervention strategies were developed collaboratively by authors SC, ML and CA by following the systematic process of the BCW (e.g. identifying intervention functions and BCTs by applying the APEASE criteria; see Supplementary Materials S2).

Results

Patterns of HPD use

From the questionnaire relating to HPD use, 42.5% \( (n = 34) \) of early-career musicians indicated that they use HPDs on average at least once a week (i.e. regular users), 35% \( (n = 28) \) indicated that they use HPDs on average less than once a week (i.e. occasional users), and 22.5% \( (n = 18) \) indicated that they never use HPDs (Figure 1(a)). The most common type of HPD used is high-fidelity musicians’ earplugs (60.3%; \( n = 38 \)), followed by single-use soft foam earplugs (23.8%; \( n = 15 \)), custom-moulded earplugs (14.3%; \( n = 9 \)), and other: ear defenders (1.6%; \( n = 1 \)) (Figure 1(b)).

A breakdown of the frequency of HPD use by musical activity can be seen in Figure 1(c). HPDs are used most frequently for recreational activities, compared with activities in which the musicians are required to play an instrument (e.g. personal practice, group rehearsals and performances). Of the activities that require playing an instrument, musicians use HPDs more often in group rehearsals and less often for personal practice or performances. HPDs are used least often during teaching activities (i.e. giving lessons to others).

Barriers and facilitators to HPD use

Several themes were generated from the thematic analysis. Specifically, six barriers to and four facilitators of HPD use were identified from the participant interviews, irrespective of whether participants use HPDs or not, the frequency of use, and the activities that HPDs are used for. These barriers/facilitators were mapped to the COM-B model/TDF domains (Table 1). Most barriers/facilitators were mapped to more than one TDF domain and all 14 TDF domains/six COM-B components were utilised. A detailed description of these broad barriers/facilitators, along with additional supporting quotations, is included in the Supplementary Materials (S3).

\[ \text{Figure 1. (a) Frequency of HPD use by early-career musicians; (b) type of HPDs most commonly used; (c) frequency of HPD use for different music-related activities.} \]
### Table 1. Barriers to and facilitators of hearing protection device use arranged according to the Capability, Opportunity, Motivation model of behaviour (COM-B) and the Theoretical Domains Framework (TDF).

<table>
<thead>
<tr>
<th>Barrier/Facilitator</th>
<th>Description</th>
<th>Key quote(s)</th>
<th>COM-B components</th>
<th>TDFs</th>
<th>Intervention functions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detrimental vs. No impact of HPDs on music listening/playing/enjoyment</td>
<td>Whether HPD use influences musical activities dictates whether they are used or not. This may depend on the musical context (e.g. recreational use vs. performance). High-fidelity/quality earplugs that have less of an impact may be more likely to be used.</td>
<td>Barrier - “…it’s quite tough to wear ear protection because I just can’t hear what I’m doing…” – Participant 18 – Cellist Facilitator - “…i think it’s quite easy to get used to wearing hearing protection and still play within an ensemble or play on your own…” – Participant S8 - Percussionist</td>
<td>Physical capability • Physical opportunity</td>
<td>Skills, Memory, attention and decision processes • Reinforcement • Emotional • Social/professional role and identity • Beliefs about capabilities</td>
<td>Tra, Env, Ena</td>
</tr>
<tr>
<td>Lack of concern vs. Concern about hearing problems</td>
<td>The level of concern about developing noise-induced hearing loss and/or tinnitus dictates whether HPDs are used or not. This may be contingent on perceived necessity, priorities, personal or anecdotal experience of hearing problems, and the level of knowledge about the risks of hearing damage and how to prevent them.</td>
<td>Barrier - “We’re not suffering from it yet, so it’s not a major problem.” – Participant 76 - Clarinet player Facilitator - “…we only get one ear set of ears, I think it’s important to look after them now so that I can still do music 20, 30 years down the line.” – Participant 28 - Oboe player</td>
<td>Psychological capability • Automatic motivation • Reflective motivation • Physical opportunity</td>
<td>Knowledge • Memory, attention and decision processes • Reinforcement • Emotion • Optimism • Beliefs about consequences • Goals • Environmental context and resources</td>
<td>Edu, Tra, Ena</td>
</tr>
<tr>
<td>Social pressures</td>
<td>Perceived pressures in the form of stigma and taboo may prevent HPD use, but normalising and encouraging HPD use may help to facilitate.</td>
<td>Barrier - “I think it’s one of those topics people almost like to try and brush under the carpet a bit, it’s not really sort of cool to talk about it…” – Participant 25 – Violinist Facilitator - “…I think it’s something that’s kind of growing in our kind of world, more and more people are using earplugs.” – Participant 47 - Trumpet player</td>
<td>Automatic motivation • Reflective motivation • Social opportunity</td>
<td>Psychological capability • Knowledge • Memory, attention and decision processes • Reinforcement • Emotion • Optimism • Beliefs about consequences • Intentions • Goals • Environmental context and resources</td>
<td>Tra, Inc, Coe, Env, Per, Inc, Coe, Mod, Ena, Edu, Per, Mod, Ena</td>
</tr>
<tr>
<td>Lack of access vs. Ease of access to HPDs</td>
<td>Having HPDs readily available or not dictated their use. All music students were previously provided with high-fidelity musicians’ earplugs as part of their enrolment at the Royal Northern College of Music. Therefore, a lack of access may be due to forgetting or losing HPDs.</td>
<td>Barrier - “…it’s not something that’s at the forefront of my mind to just go, wait, let me just grab that.” – Participant 35 – Voice Facilitator - “…I’m right at the back of the second violins next to the brass section, I’ll just, you know, have them on my stand and I’ll just put them in.” – Participant 60 - Violinist</td>
<td>Psychological capability • Automatic motivation • Reflective motivation • Physical opportunity</td>
<td>Memory, attention and decision processes • Reinforcement • Emotional • Social/professional role and identity • Beliefs about consequences • Environmental context and resources</td>
<td>Tra, Env, Ena</td>
</tr>
<tr>
<td>Discomfort and poor fit</td>
<td>Dislike of the physical sensation of HPDs in the ears or problems with fit and placement. Musicians may not take the time to persevere with their use. Although early-career musicians suggested that they may be more likely to use high-fidelity musicians earplugs that do not impact music performance, they also noted that these may be too expensive.</td>
<td>Barrier - “…sometimes they’re uncomfortable, they’re a bit of a pain to get in and out…” – Participant 56 - Tuba player</td>
<td>Reflective motivation • Physical opportunity</td>
<td>Beliefs about consequences • Environmental context and resources</td>
<td>Tra, Res, Env, Ena</td>
</tr>
<tr>
<td>Affordability of high-fidelity HPDs</td>
<td>Although early-career musicians suggested that they may be more likely to use high-fidelity musicians earplugs that do not impact music performance, they also noted that these may be too expensive.</td>
<td>Barrier - “…I would use it all the time if I could but there are quite a lot of situations where you can’t wear hearing protection, or at least you can’t wear the hearing protection that I can afford.” – Participant 55 - Clarinet player</td>
<td>Physical opportunity</td>
<td>Beliefs about consequences • Environmental context and resources</td>
<td>Tra, Res, Env, Ena</td>
</tr>
</tbody>
</table>

Identifying intervention functions

Possible intervention functions linked to each TDF domain are also shown in Table 1. After using the APEASE criteria to assess each intervention function’s suitability for overcoming barriers/promoting facilitators, two potential candidate intervention functions were identified: ‘Environmental restructuring’ and ‘Persuasion/Modelling’. For a full list of all intervention functions, their definitions, and application of the APEASE criteria for each TDF domain, see Supplementary Materials S2 – Step 5.

Environmental restructuring (i.e. changing the physical or social context) meets the APEASE criteria for addressing a lack of awareness of sound levels and the belief that HPDs are not needed (i.e. Barrier – Lack of concern). Environmental cues may also prevent forgetting and prompt HPD use (Barriers – Lack of concern; Lack of access). Corresponding TDF domains include ‘Memory, attention and decision processes’ and ‘Environmental context and resources’.

Persuasion (i.e. using communication to induce positive or negative feelings or stimulate action) and Modelling (i.e. providing an example for people to aspire to imitate) intervention functions were combined given the potential for overlap in their definitions (e.g. providing an example to induce positive feelings or stimulate action). Moreover, persuasion and modelling are simultaneously linked to all six TDF domains relating to Reflective Motivation, plus TDF ‘Emotion’ (see Table 1 and Supplementary Materials S2 – Step 5), and so could be used in conjunction to address several barriers to HPD use. In particular, these combined intervention functions could address breaking down social stigmas and encouraging others to use HPDs (Barrier – Social pressures), and reducing concerns about the impact of using HPDs on career prospects and success (Barrier – Detrimental impact on music listening/playing/enjoyment). Corresponding TDF domains include ‘Behavioural regulation’, ‘Emotion’, ‘Social influences’, ‘Social/professional responsibility’ and all TDF domains underpinning ‘Reflective motivation’ of the COM-B model (see Table 1).

Identifying behaviour change techniques (BCTs)

For simplicity, only BCTs which meet the APEASE criteria for Environmental restructuring and Persuasion/Modelling are reported. For a full list of all related BCTs and application of the APEASE criteria, see Supplementary Materials S2 – Step 7.

Environmental restructuring

The more commonly used BCTs that serve Environmental restructuring are ‘Prompts/cues’ (i.e. introducing or defining environmental or social stimuli with the purpose of prompting of cueing the behaviour) and ‘Restructuring the physical environment’ (i.e. changing, or advising to change the physical environment in order to facilitate performance of the wanted behaviour). A less frequently used BCT that also meets the APEASE criteria is ‘Exposure’ (i.e. providing systematic confrontation with a feared stimulus to reduce the response to a later encounter).

Based on these selected BCTs, several possible intervention strategies are proposed:

- Use Prompts/cues communicated verbally or via email/text/calendar notifications to inform students that upcoming rehearsals/performances may exceed safe exposure limits, and therefore remind them to bring HPDs and to use throughout the performance.
- Advise students to have hearing protection about their person at all times (e.g. in instrument case, bags, connected to keys, etc.) for ease of access (i.e. Restructuring the physical environment).
- Provide visual Prompts/cues such as posters and signage to notify students that they are entering a potentially noisy environment.
- Provide visual Prompts/cues such as sound level metres that display decibels in real time and/or signify when volume levels exceed safe limits.
- Advise students to use HPDs regularly in a variety of musical and non-musical contexts (e.g. quieter personal practice and loud ensembles) so that they become used to attenuated sound levels and/or less fearful of the impact of HPDs on music listening and performance (i.e. Exposure; also see BCTs ‘Behavioural practice/rehearsal’ and ‘Habit formation’).

These strategies may overlap and could be combined into a single strategy to: i) ensure students have access to HPDs at all times, and ii) ensure that students use HPDs when required.

Persuasion/modelling

The more commonly used BCTs that serve Persuasion and Modelling are ‘Credible source’ (i.e. presenting verbal or visual communication from a credible source in favour or against the behaviour) and ‘Demonstration of the behaviour’ (i.e. providing an observable sample of the performance of the behaviour), respectively. Less frequently used BCTs that also serve Persuasion include ‘Verbal persuasion about capability’ (i.e. telling the person that they can successfully perform the wanted behaviour, arguing against self-doubts), ‘Identification of self as role model’ (i.e. informing them that one’s own behaviour may be an example to others), ‘Information about others’ approval’ (i.e. providing information about other people’s approval/disapproval of the behaviour), and ‘Social comparison’ (i.e. drawing attention to others’ performance for comparison with their own performance).

Using these BCTs, a potential intervention strategy involves teachers/staff and/or influential musicians (i.e. Credible source) championing the use of HPDs by being seen to use HPDs (i.e. Demonstration of the behaviour/visual communication), discussing the benefits, and providing advice and support to students in terms of performing while using HPDs (i.e. Verbal persuasion about capability). This may implicitly encourage students to use HPDs and to discuss the topic with their peers (i.e. Identification of self as role model) and start to shift social norms towards regular HPD use. Students could also be explicitly informed about approval of HPD use from/by credible sources (i.e. Information about other’s approval) and patterns of HPD use and approval amongst fellow musicians (i.e. Social comparison), and encouraged to provide peer-to-peer support (i.e. Identification of self as role model).

Discussion

Overall, 77.5% of early-career musicians in this study reported using HPDs at some point for music-related activities. This figure is higher than has been recently reported for professional musicians in the UK (66.5%; Greasley et al. 2018), and could signify a promising trend in greater uptake of HPDs for young
musicians, potentially due to conservation strategies already in place. Nevertheless, only 42.5% of early-career musicians in this study reported (semi-) regular HPD use (i.e. at least once a week). Tufts and Skoe (2018) measured week-long dosimetry in college-aged music students, revealing that 74% of music students exceeded the recommended daily exposure limits (see NIOSH 1998) on three or more days of the week, compared with just 13% of non-musicians. Accordingly, the need to address irregular and non-use of HPDs in early-career musicians is justified.

Previous interventions to promote HPD use in musicians do not appear to be based on a model of behaviour change, and are often based on the assumption that musicians require more education on hearing loss and HPD use. This is despite evidence to suggest that musicians are more aware of noise-induced hearing problems, and have healthier attitudes towards hearing conservation, than non-musicians (Chesky et al. 2009a). It is important to emphasise that we are not denouncing education on hearing loss and hearing conservation for musicians. Education is instrumental in improving knowledge and attitudes and has been shown to be effective at increasing HPD uptake for school-aged musicians (Auchter and Le Prell 2014; Palmer 2009). Moreover, early-career musicians in the current study highlighted the importance of educating musicians about the dangers of noise exposure from a younger age. However, it is not clear that repeatedly providing education is an effective strategy for early-career musicians who are generally aware of the risks. As such, it is imperative to explore alternative – or supplementary – intervention functions and BCTs that might further promote regular HPD use in early-career musicians.

From the semi-structured interviews with early-career musicians, we identified key barriers to HPD use that were consistent with those found in previous research, such as detrimental impact on musical listening and performance, a general lack of concern, and social pressures (e.g. Patel 2008). After mapping these barriers according to the COM-B/TDF framework, we were able to systematically develop several intervention strategies using a range of BCTs. These strategies can be broadly grouped according to the two intervention functions from which they were developed: Environmental restructuring and Persuasion/Modelling.

**Environmental restructuring**

We suggest numerous strategies that utilise BCTs to manipulate the physical environment to evoke behaviour change. We propose the use of Prompts/cues to remind students about upcoming rehearsals and performances that are likely to be loud. This strategy aims to overcome several barriers such as a lack of access to HPDs due to poor planning or forgetting, and a lack of concern due to the belief that HPDs are not needed. This could be a simple verbal reminder from teachers and staff, a timetable that documents upcoming loud events, or a text/email/calendar notification system. In support, O’Brien, Driscoll, and Ackermann (2012) showed that professional orchestras providing personalised weekly noise risk assessments as part of their hearing conservation programme also had the highest use of HPDs. However, it is uncertain how practicable this strategy would be for early-career musicians whose practice and rehearsal schedules may be more spontaneous and unpredictable, and which are often self-managed independently of centrally timetabled classes. Therefore, a supplementary strategy is to advise students to have HPDs about their person at all times to ensure easy access, assuming that these have been provided as part of their course of study.

An alternative suggestion utilising Prompts/cues is to display signage to warn students about noisy environments and to advise that HPDs are worn. Given the dynamic nature of music, we also propose the use of sound-level metres which provide a visual display of instantaneous, continuous and/or cumulative noise exposure to cue HPD use if defined levels are exceeded (e.g. 85 dB A; Control of Noise at Work Regulations 2005). These two strategies aim to address a lack of concern due to a lack of awareness of potentially damaging noise levels. Powell and Chesky (2017) trialled a similar strategy in jazz ensembles using an ambient information system to provide real-time visualisation of dosimeter data. In their study, music instructors were the intended end-users of these visual cues so that they could adjust their teaching methods to manage noise exposure. Here we are suggesting a similar intervention to influence behaviour change in early-career musicians directly, given that many of their musical activities will not have an instructor present. As opposed to reducing the duration and level of noise in ensemble settings, the intended outcome is increased HPD use, especially as student musicians have less control over the volume of other musicians’ instruments and may not be able to reduce their exposure time because of the demands of their course of study.

An additional strategy is to advise students to use HPDs regularly across a variety of different musical and non-musical contexts so that they get acclimatised to attenuated sound levels and become less concerned by the potential impact of HPDs on listening to music and performing (i.e. Exposure; Behavioural practice/rehearsal; Habit formation). O’Brien et al. (2014) reported that, in an orchestra with high levels of HPD use, 88% of professional musicians who had been using custom-moulded musicians’ earplugs for 10-20 years still found it difficult – if not impossible – to perform effectively while using HPDs. Given the pressure to achieve high musical standards at music colleges, it is uncertain whether music students will be willing to compromise their musical performance to protect their hearing, where there may not be a suitable setting or enough time during their course of study to persevere with HPD use (see Barrier – Detrimental impact of HPDs on music listening/playing/enjoyment). Musicians’ dissatisfaction with the impact of HPDs on music listening and playing also highlights fundamental flaws with the design, specification and fitting of high-fidelity musicians’ earplugs, which need addressing (O’Brien, Ackermann, and Driscoll 2014; Zander, Spahn, and Richter 2008). Indeed, the detrimental impact of HPDs on music listening and performance is not necessarily subjective, given that it has been shown that high-fidelity musicians’ earplugs can lead to an occlusion effect (Bernier and Voix 2013; Killion 2012), sound localisation difficulties (Chasin and Chong 1999), and altered spectral characteristics (Chesky and Amlani 2015); they have also been shown to alter the sound level and spectrum of played sounds (Kozlowski, Zera, and Młynski 2011) and result in less resonant choral singing (Cook-Cunningham 2019).

**Persuasion/modelling**

We have also suggested an intervention strategy that utilises BCTs that provide an example for early-career musicians to aspire to, and thus encourage HPD use. For example, we suggest using a credible source in the form of teachers, staff and established professional musicians to be seen to use HPDs (Demonstration of the behaviour/Visual communication) and to
promote their use (Verbal persuasion). The ultimate goal of this strategy is to challenge the social norms/taboo surrounding HPD use (Social comparison; Information about other’s approval; Identification of self as role model), either explicitly or implicitly, so that HPD use becomes more acceptable and ubiquitous amongst early-career musicians.

As opposed to targeting early-career musicians directly, this intervention strategy first relies upon others to use HPDs and to act as role models. This may prove to be difficult to implement as not all staff/teachers/established professionals may be willing to use HPDs and they may also face the same barriers to HPD use as music students (O’Brien, Driscoll, and Ackermann 2012; O’Brien, Ackermann, and Driscoll 2014; Zander, Spahn, and Richter 2008). Consequently, some students may be disadvantaged if their main instructor cannot be persuaded to use HPDs. In addition, while celebrity endorsements to promote HPD use has been suggested previously (Federman and Picou 2009), the effectiveness of such a strategy for musicians is yet to be determined and it might not be practicable or affordable to involve highly influential musicians. As such, additional data may need to be gathered from the staff/teachers/established professionals to assess whether they are willing and able to model and persuade, in order to determine whether this proposed intervention meets the APEASE criteria.

Using Persuasion/Modelling to change social norms is also unlikely to happen immediately and may take months or years to take effect. Nevertheless, once using HPDs becomes commonplace, it is unlikely to stop being so, thus leading to sustained HPD use. Rather, BCTs relating to Environmental restructuring, especially Prompts/cues, may be effective for encouraging immediate HPD use, but it is less certain whether this would lead to long-lasting habit formation, and the removal/absence of reminders might lead to non-use. Accordingly, it may be beneficial to use both Persuasion/Modelling and Environmental restructuring strategies to promote HPD uptake and sustained use. Multiple intervention strategies should be implemented with caution, however, as they may interact, making it difficult to evaluate their individual effectiveness (cf. O’Brien, Driscoll, and Ackermann 2012).

Alternative solutions to HPD use

HPD use is often considered a last resort in other high-risk industries (e.g. construction), where avoiding noise or reducing the noise level at source is the safest option (Control of Noise at Work Regulations 2005). However, noise is an intended and unavoidable consequence of being a musician. Reducing the volume may also be dependent on other players and sound technicians. Therefore, reducing noise at the source is a less practical target for intervention. Managing noise exposure by taking regular breaks and rotating rosters may be a promising option for large professional orchestras (O’Brien, Driscoll, and Ackermann 2015, 2012) but it is less feasible for early-career musicians who are undertaking an intensive course of musical training.

Acoustic treatment of practice and rehearsal spaces is also a potentially useful method of reducing the risk of noise-induced hearing problems as musicians do not need to play as loudly to compete with reverberation, other instruments, or environmental noise. However, these facilities are costly, may not be readily accessible, and may cause musicians to play louder to compensate for sound absorption (O’Brien, Driscoll, and Ackermann 2012). Acoustic screens may be useful for preventing noise exposure from other musicians’ instruments and are commonly used in large ensembles, yet the level of attenuation may only be between 3-6 dB A and could increase noise exposure through reflected sound (Libera and Mace 2010; O’Brien Wood and Ackermann 2013; Williams 1995). In addition, acoustic screens are not used regularly by smaller ensembles, or in recording studios or orchestra pits with limited space, and so are not a practical solution on their own (Patel 2008).

Accordingly, we consider increasing HPD uptake as the most promising behavioural target in terms of impact on the desired outcome, feasibility of change, and measurability (see Supplementary Materials S2 - Step 2; Michie, Atkins, and West 2014).

Limitations

The BCW provides an evidence-driven, transparent and repeatable method for designing, implementing and evaluating interventions that can be applied to a variety of contexts (Michie, Atkins, and West 2014, Michie, van Stralen, and West 2011). However, it has been suggested that even the systematic process of the BCW may not be able to address all personal and external factors that affect behaviour, and so will not be able to offer a “one size fits all” solution for the purposes of effecting behaviour change (Ogden 2016). Additionally, it is advised that health psychologists explore the range of theories that are available without the restriction of a dominant unified model (Ogden 2016; Peters and Kok 2016). It is possible that other models and theories of behaviour change may be more suitable, either alone or in conjunction with the BCW, in the context of hearing conservation. For example, ‘Intervention Mapping’ has been used to develop a program to prevent hearing loss among farmworkers (Fernandez, Bartholomew, and Alterman 2009).

The suggested intervention strategies are based on the difficulties faced by early-career musicians only. Despite these barriers to HPD use being similar to those identified in school-aged and professional musicians (e.g. Patel 2008), we have evaluated intervention functions and BCTs using the APEASE criteria for early-career musicians’ circumstances (see Supplementary Materials S2). Therefore, caution should be taken if applying these intervention strategies to other groups of musicians. We advise that researchers consider the context of HPD use in their target population in order to develop intervention strategies for hearing conservation using the BCW.

Due to the large number of measures conducted as part of the wider investigation (lasting approximately 3 hours per participant; see Couth et al. 2020), interviews were shorter than is typically recommended for a semi-structured interview (i.e. 30 minutes or more; DiCicco-Bloom and Crabtree 2006) and so the depth of responses may have been limited. Nevertheless, including a small number of general questions allowed participants to voice the issues that were most pertinent to them, and without bias from potentially leading questions. Furthermore, by including a relatively large participant sample for a qualitative study design (cf. Barker, Atkins, and de Lusignan 2016), we were able to capture a wide variety of highly relevant views and opinions within a short time frame.

Conclusion

This study aimed to determine the patterns of HPD use in early-career musicians, identify the barriers to and facilitators of HPD use, and to follow the systematic process of the BCW to propose intervention strategies for improving uptake and sustained use.
To our knowledge, this is the first time that the BCW has been used for developing interventions in the context of hearing conservation. In addition, insights were garnered from 80 early-career musicians, which is a relatively large sample size for this type of qualitative research (cf. Barker, Atkins, and de Lusignan 2016). While over three quarters of early-career musicians in this study reported some use of HPDs, less than half regularly use them. Through semi-structured interviews we identified the main reasons for non-use of HPDs by early career musicians. These barriers to HPD use were mapped onto a theoretical health behaviour framework (COM-B/TDF), and then used to select appropriate intervention functions and BCTs to develop strategies to improve the uptake and sustained use of HPDs. We suggest using reminders to prompt the use of HPDs in noisy settings, and using credible role models to implicitly and explicitly promote the use of HPDs and to challenge the social stigma attached to wearing HPDs. The next step is to pilot one or two of these intervention strategies to determine their practicability, acceptability, and effectiveness for increasing uptake and long-term use of HPDs. The goal is to make the use of HPDs ubiquitous in loud musical settings and reduce noise-induced hearing damage in musicians.

Note
1. NB. One participant noted equal use of foam and musicians’ earplugs, hence total numbers of participants using HPDs across the different types of HPD equals 63, despite only 62 participants reporting HPD use.

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