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.

Keywords

Hearing loss; tinnitus; musicians; hearing protection; interventions; behaviour change

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 et al., 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) (Laitinen, 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 et al., 2015; O'Brien et al., 2014; Patel, 2008; Zander et al., 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 et al., 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 (Shepheard 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 et al., 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 et al., 2015, 2012; O'Brien et al., 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 focused 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 et al., 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 et al., 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 et al., 2014, 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 et al., 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 et al., 2018, 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, 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 et al., 2020a, 2020b). 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 et al., 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 et al., 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, Restriction, Environmental restructuring, Modelling and Enablement (Abraham et al., 2008; Michie et al., 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 et al., 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 et al., 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 et al., 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 (Fig. 1a). 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)[1], custom-moulded earplugs (14.3%; n = 9), and other: ear defenders (1.6%; n = 1) (Fig. 1b).

A breakdown of the frequency of HPD use by musical activity can be seen in Figure 1c. 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).

[Figure 1 here]

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).

[Table 1 here]

[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.

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 meters 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 et al. (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 meters 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. Powel 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 et al., 2014; Zander et al., 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 (Kozłowski et al., 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 et al., 2012; O'Brien et al., 2014; Zander et al., 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 et al., 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 et al., 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 et al., 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 et al., 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 et al., 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 et al., 2014, 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 et al., 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 et al., 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 et al., 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.

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Figure captions

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.

Figure 1

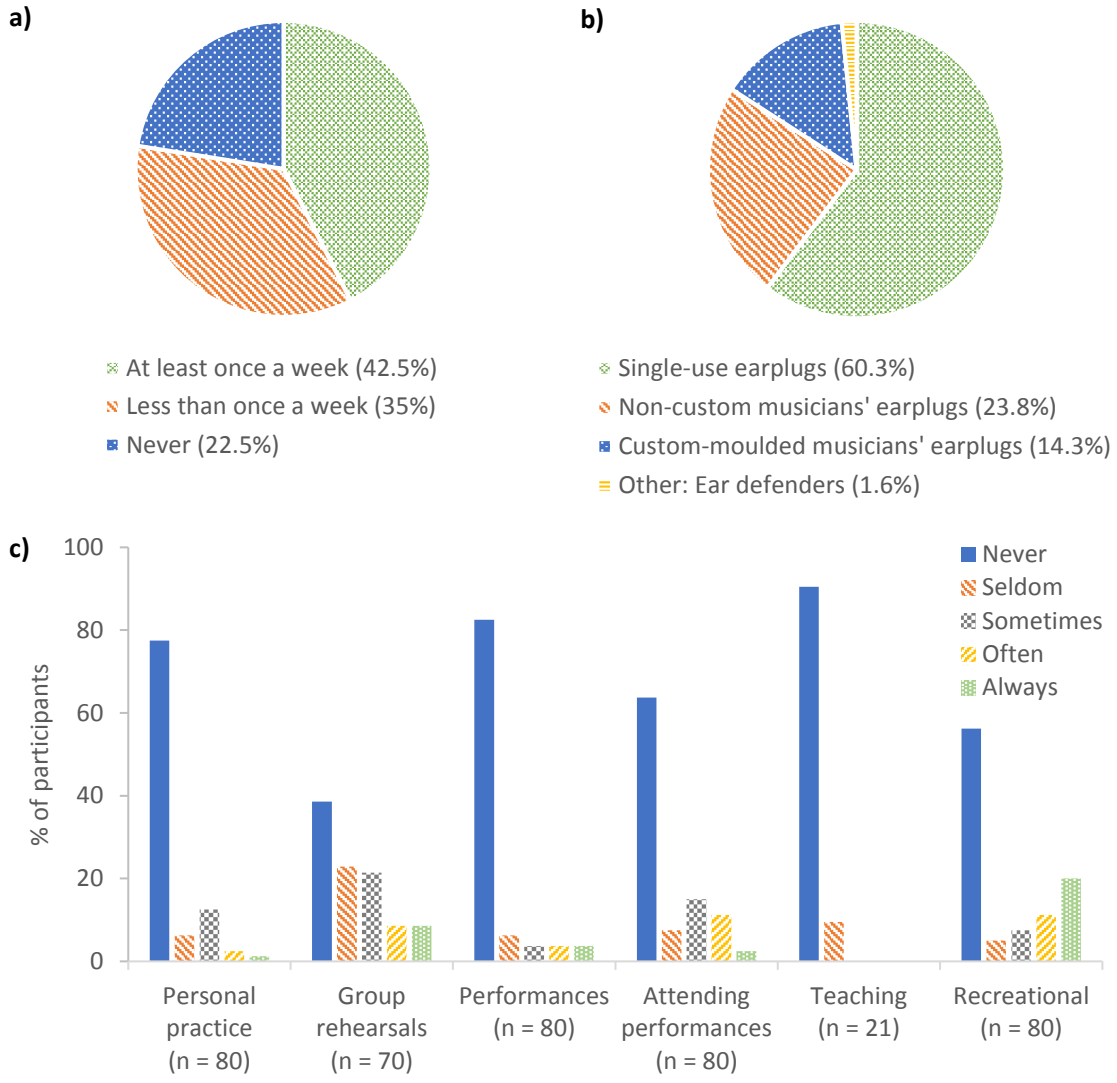
a)
At least once a week (42.5%)
Less than once a week (35%)
Never (22.5%)
b)
Single-use earplugs (60.3%)
Non-custom musicians' earplugs (23.8%)
Custom-moulded musicians' earplugs (14.3%)
Other: Ear defenders (1.6%)
c)
% of participants
100
80
60
40
20
0
Never
Seldom
Sometimes
Often
Always
Personal practice (n = 80)
Group rehearsals (n = 70)
Performances (n = 80)
Attending performances (n = 80)
Teaching (n = 21)
Recreational (n = 80)

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).

Barrier/Facilitator	Description	Key quote(s)	COM-B components	TDFs	Intervention functions*
Detrimental vs. No impact of HPDs on music listening/playing/enjoyment	Whether HPD use influences musical activities dictates whether they are used on 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.	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 58 - Percussionist	- Physical capability - Psychological capability - Automatic motivation - Reflective motivation - Physical opportunity	- Skills - Memory, attention and decision processes - Reinforcement - Emotion - Social/professional role and identity - Beliefs about capabilities - Optimism - Beliefs about consequences - Goals - Environmental context and resources	- Tra - Tra, Env, Ena - Tra, Inc, Coe, Env - Per, Inc, Coe, Mod, Ena - Edu, Per, Mod - Edu, Per, Mod, Ena - Edu, Per, Mod, Ena - Edu, Per, Mod - Edu, Per, Inc, Coe, Mod, Ena - Tra, Res, Env, Ena
Lack of concern vs. Concern about hearing problems	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	Barrier – "*We're not suffering from it yet, so it's not a major problem*." – Participant 76 - Clarinet player Facilitator - "*…we only get one 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	- Psychological capability - Automatic motivation	- Knowledge - Memory, attention and decision processes - Reinforcement - Emotion - Optimism	- Edu - Tra, Env, Ena - Tra, Inc, Coe, Env - Per, Inc, Coe, Mod, Ena

	level of knowledge about the risks of hearing damage and how to prevent them.		- Reflective motivation - Physical opportunity	- Beliefs about consequences - Intentions - Goals - Environmental context and resources	- Edu, Per, Mod, Ena - Edu, Per, Mod - Edu, Per, Inc, Coe, Mod - Edu, Per, Inc, Coe, Mod, Ena - Tra, Res, Env, Ena
Social pressures	Perceived pressures in the form of stigma and taboo may prevent HPD use, but normalising and encouraging HPD use may help to facilitate.	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	- Automatic motivation - Reflective motivation - Social opportunity	- Reinforcement - Social/professional role and identity - Social influences	- Tra, Inc, Coe, Env - Edu, Per, Mod - Res, Env, Mod, Ena
Lack of access vs. Ease of access to HPDs	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.	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	- Psychological capability - Physical opportunity	- Memory, attention and decision processes - Behavioural regulation - Environmental context and resources	- Tra, Env, Ena - Edu, Tra, Mod, Ena - Tra, Res, Env, Ena
Discomfort and poor fit	Dislike of the physical sensation of HPDs in the ears or problems with fit and placement. Musicians may not	Barrier – "*…sometimes they're uncomfortable, they're a bit of a pain to get in and out*…" – Participant 56 - Tuba player	- Reflective motivation - Physical opportunity	- Beliefs about consequences	- Edu, Per, Mod - Tra, Res, Env, Ena

	take the time to persevere with their use.			- Environmental context and resources	
Affordability of high-fidelity HPDs	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.	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	- Physical opportunity	- Environmental context and resources	- Tra, Res, Env, Ena

*Intervention functions: Edu = Education, Per = Persuasion, Inc = Incentivisation, Coe = Coercion, Tra = Training, Res = Restriction, Env = Environmental restructuring, Mod = Modelling, Ena = Enablement.

Supplementary materials

S1. Standard for Reporting Qualitative Research - Research design and methods (O'Brien et al., 2014)

Qualitative approach and research paradigm

No defined approach was used in the current study. The methodology may align with phenomenology (i.e. gathering descriptions of the lived experiences of hearing loss and hearing protection use by early-career musicians musicians), although thematic analysis has been described as falling within the remit of ethnography, grounded theory, discourse analysis and phenomenology approaches (Kiger and Varpio, 2020). Indeed, the boundaries between different interpretive approaches has been described as "porous" (Starks and Trinidad, 2007) and it has been argued that thematic analysis could be considered a qualitative method on its own (Braun and Clarke, 2006).

The systematic process of the Behaviour Change Wheel (BCW) was used as a framework to understand the target behaviour (i.e. non-use of HPDs), identify intervention options (i.e. COM-B/TDF), and identify content and implementation options (i.e. intervention functions and behaviour change techniques) (Michie et al. 2014; see supplementary materials S2).

At the time of writing, the first author (SC) holds a critical realist view. Specifically, the author aligns to the view that the aim of scientific research is to investigate relationships between what we experience (i.e. the empirical/observable domain) and the underlying mechanisms and structures (i.e. the 'real'/unobservable domain). Thus, critical realism allows for the idea of multiple perspectives (i.e. positivist and constructionist) and is compatible with a mixed methods approach to research (Maxwell and Mittapalli, 2010).

Researcher characteristics and reflexivity

The research team comprises a wide variety of research backgrounds including cognitive neuroscience, audiology, behavioural science, psychophysics, epidemiology and music psychology. Several authors identify as musicians, and several also experience a range of hearing difficulties including tinnitus, speech-in-noise difficulties, and permanent hearing loss. All authors hold the view that high levels of noise exposure, including from music-related activities, has the potential to cause damage to hearing, which is based on empirical findings from the research team (Couth et al., 2020, 2019) and the literature (for a review see Zhao et al. 2010). Accordingly, the authors consider the use of hearing protection devices to be a favourable health behaviour.

None of the authors had pre-existing relationships with the participants prior to their participation in this study, and none of the authors had any assumptions or presuppositions about the data other than knowledge gathered from the literature.

All interviews were conducted by the first author (SC), who has a background in cognitive neuroscience and psychology. He has been using quantitative and qualitative research methods for over 10 years to collect data from a wide variety of participant groups, including from clinical and non-clinical populations, in a variety of different contexts, and is experienced at building a rapport on a one-to-one basis with participants.

Context

Participation in this qualitative study was part of a larger longitudinal project investigating hearing health in early-career musicians (Couth et al., 2020). Participants were invited back once a year, for up to 2 years (3 visits total) to examine changes to their hearing during this period. The qualitative part of this study to investigate barriers and facilitators of hearing protection use was conducted once only during the initial baseline visit. Interviews were conducted prior to conducting any objective hearing tests that could influence musicians' views on noise exposure, hearing loss, and hearing protection use. All baseline visits were completed between March 2017 and June 2018.

Interviews were conducted approximately 30 minutes into the testing session after participants had received a detailed overview of the aims of the wider project from the researcher, provided written consent, had been offered refreshments, and had completed several other background questionnaires relating to demographics, health and lifestyle. As such, the researcher had opportunity to develop a rapport with participants before the interview. Developing a good rapport with participants was a vital aspect of this project to ensure ongoing participation in the longitudinal study. Indeed, all participants indicated that they were happy to be contacted about the follow-up tests and 69 musicians returned the following year to repeat their hearing assessments.

All interviews were conducted in audiology research labs at the Manchester Centre for Audiology and Deafness; The University of Manchester. These facilities provide a quiet and distraction-free space for conducting one-to-one interviews.

Sampling strategy

Eighty musicians (age range = 18-26 years; women n = 39) were recruited from the Royal Northern College of Music and the University of Manchester using a volunteer sampling method. Interviews were conducted with all participants as part of their involvement in the larger research project. This

sample size is relatively large for qualitative studies using the BCW framework. For example, the study by Barker et al. (2016) included 10 participants, Rolfe and Gardner (2016) included 22 participants, and Nickbakht et al. (2020) included 28 participants. It is possible that saturation could have been achieved with fewer participants, but the musicians recruited to the study were heterogenous in terms of the instruments that they play and their previous musical experience. Therefore, it was important to include a representative sample across all classifications of instruments and experiences to capture a wide range of thoughts and opinions on NIHL and HPD use. Instrument classifications included 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).

All participants were undertaking – or were within one year of having completed – a degree (bachelors or masters) in performance-based musical studies, and thus were all deemed to be "early-career". We were interested in early-career musicians in particular as they progress through a period of intensive musical training (both within and outside of their host institute), and so interventions to protect hearing longevity and establish life-long hearing protection habits may be vital at this stage.

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.

Ethical issues pertaining to human subjects

The study was approved by the University of Manchester Research Ethics Committee (REF: ethics/16388) in accordance with the Declaration of Helsinki 2013. All participants provided informed consent and all data (both recorded and transcribed) was pseudonymised so that it was only identifiable to the interviewer (author SC). All audio recordings were deleted after transcription was completed.

Data collection methods

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 were recorded for later transcription using the voice recorder on the interviewer's encrypted and password protected smartphone.

Although it is possible to develop interview questions which specifically address each of the components of the COM-B model/TDF (Michie et al., 2014), we chose to ask a small number of general questions which allowed each participant to voice the issues that were most salient to them as an individual, rather than providing a response which was prescribed/forced by the interview question. In addition, this allowed the authors to use these responses to generate broad themes using an inductive approach, which we were then able to assign to the most appropriate TDF components retrospectively (see *Data analysis*). McGowan, Powell and French (2020) suggest that rigid adherence to the TDFs in data collection and analysis (i.e. a deductive approach) may result in important behavioural determinants being overlooked. Instead, the authors propose that the TDF should be used flexibly to optimise its use in exploratory qualitative research.

Due to the large number of measures conducted as part of the wider investigation (lasting approximately 3 hours per testing session), the number of questions included in the interviews was kept to a minimum to also avoid participant fatigue and boredom. Interviews ranged from 2-9 minutes in duration, which is shorter than is typically recommended for a semi-structured interview (i.e. 30 minutes or more; DiCicco-Bloom and Crabtree, 2006) and so the reliability and/or validity of responses may have been limited. Nevertheless, by including a relatively large participant sample, we were able to capture a wide variety of highly relevant views and opinions within a short time frame.

Units of study

See *Sampling strategy* and *Data collection methods*

Data processing

Each interview was transcribed verbatim using a professional transcription service (1st Class Secretarial, UK; https://www.1stclass.uk.com/). Transcriptions of each interview were provided as individual Microsoft Word files. Each Word file was imported into NVivo (version 11; QSR International) to assist with conducting the thematic analysis.

Data analysis

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. All themes were generated irrespective of any behavioural framework (i.e. COM-B model/TDF) to avoid constraining the interpretation of the data. Only once all themes had been finalised were they then mapped directly to the relevant TDF domains based on the description of each domain (Michie et al., 2014). All themes were mapped to at least one TDF, and there were no themes that could not be mapped to the framework. 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).

Techniques to enhance trustworthiness

Trustworthiness of the qualitative research is based on the criteria set out by Lincoln and Guba (1985), which includes credibility, transferability, dependability and confirmability.

Credibility

To ensure data credibility, we used data triangulation by interviewing participants from a range of musical backgrounds (e.g. genres, instrument classification, years of experience, etc.), a variety of subjective hearing difficulties (e.g. experience of tinnitus and hyperacusis; Couth et al. 2020) and varying levels of HPD use.

Investigator triangulation was applied by having two researchers (authors SC and ML) independently code the data and map themes to the TDF. The two coding authors compared codes/themes and their mapping to the TDF and discussed discrepancies with a third researcher (author CA) to reach a consensus. The development of intervention strategies involved regular discussions amongst authors SC, ML and CA until there was 100% agreement on the application of the APEASE criteria for selecting intervention functions and BCTs. All remaining authors also reviewed the generated themes and the systematic work-through of the BCW, and approved the final intervention strategies.

We also used methodological triangulation by collecting and comparing the quantitative data on HPD use patterns with the qualitative interview data. For example, reasons for non-use of HPDs were checked against usage patterns in various contexts (e.g. recreational vs. performance based) to ensure consistency amongst these sources of data.

Data credibility was also ensured through persistent observation of the data. That is, the coding authors read and reread the interview data to ensure correct interpretation, generation of themes, and mapping to the TDF. This process was further enhanced by reviewer comments on the original manuscript submission where it was recommended that we consolidate our initial set of 17 barriers and 10 facilitators into more general barriers/facilitators. This consolidation process was conducted by authors SC, ML and CA, and all authors agreed on the final consolidated set of barriers/facilitators (Table 1).

Transferability

With respect to transferability of the current findings, the proposed intervention strategies are based on barriers/facilitators for early-career musicians only (see Context and Sampling strategy). Despite these barriers to HPD use being similar to those identified in school-aged and professional musicians (e.g. Patel, 2008), intervention functions and BCTs were evaluated using the APEASE criteria for early-career musicians' circumstances. Therefore, caution should be taken if applying these intervention strategies to other musician groups. We advise that researchers consider the context of HPD use in their target population in order to develop intervention strategies.

Dependability and confirmability

The dependability (i.e. the stability/consistency) of the data analysis methods was ensured by adhering to the intervention design process outlined by the BCW (Michie et al., 2014). The dependability of the findings will be confirmed by testing the efficacy of the proposed intervention strategies and by further assessment of their acceptability amongst early-career musicians. These data and suggested refinements to the intervention strategies will be reported in any subsequent publications.

In accordance with confirmability of data, all anonymised interview transcription, initial coded themes and mapping to the TDFs (in NVivo) are available upon request from the corresponding author.

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S2. Using the Behaviour Change Wheel for designing interventions (Michie et al., 2014)

Step 1 – Define the problem in behavioural terms

The aim of this first step is to define the problem that is being addressed in behavioural terms. This is completed by answering three questions:

What behaviour?	Improving healthy hearing practices to prevent noise induced hearing damage
Where does the behaviour occur?	In all settings where sound intensity levels exceed 85 dB A (in accordance with the Control of Noise at Work Regulations 2005)
Who is involved in performing the behaviour?	Early-career musicians

Step 2 – Select the target behaviour

In this second step, it is important to consider the behaviour(s) as part of a system that does not occur in isolation. That is, the target behaviour(s) may be influenced by competing demands or other behaviours conducted by the individual, another person, or group of people. If a target behaviour is selected which is reliant on other behaviours, then this needs to be carefully considered in the design of the intervention. Therefore, the first part of this step involves creating a list of all possible behaviours which might be relevant to the problem to be solved.

Intervention designer response
Increasing HPD use uptake and retention
Avoiding/eliminating noisy settings
Managing exposure e.g. taking more breaks and moderating exposure
Playing more quietly/reducing the volume
Improving sound isolation/proofing
Use of acoustic screens

Although a number of different behaviours identified at this stage could be targeted as part of an intervention, it is recommended to focus on just one or two behaviours to begin with. By introducing behaviour change incrementally it is easier to evaluate the success of the intervention and to refine as necessary. Accordingly, the second part of this step involves deciding which target behaviour(s) seems the most promising by prioritising them based on the following criteria:

Potential target behaviours	**Impact of behaviour change (unacceptable, unpromising but worth considering, promising, very promising)**	**Likelihood of changing behaviour (unacceptable, unpromising but worth considering, promising, very promising)**	**Spillover score (unacceptable, unpromising but worth considering, promising, very promising)**	**Measurement score (unacceptable, unpromising but worth considering, promising, very promising)**
Increasing HPD use uptake and retention	Very promising	Promising	Unpromising but worth considering	Very promising
Avoid/eliminate noisy settings	Very promising	Unacceptable	Unacceptable	Very promising
Managing exposure e.g. taking more breaks and moderating exposure	Promising	Unacceptable	Unacceptable	Very promising
Playing more quietly/reducing the volume	Promising	Unacceptable	Unacceptable	Promising
Improving sound isolation/proofing	Unpromising but worth considering	Unpromising but worth considering	Promising	Promising
Use of acoustic screens	Unpromising but worth considering	Promising	Unpromising but worth considering	Unpromising but worth considering
Record selected target behaviour here:	**Increasing HPD use uptake and retention**			

Step 3 – Specify the target behaviour

Once the target behaviour has been selected, the next step is to provide specific details about the behaviour. This involves answering the following questions:

Target behaviour	Increasing HPD use uptake and retention
***Who* needs to perform the behaviour?**	Early-career musicians
***What* do they need to do differently to achieve the desired change?**	Use HPDs in all noisy (>85 dB A) settings
***When* do they need to do it?**	Before (i.e. plan ahead) and during exposure to loud sounds
***Where* do they need to do it?**	Noisy settings e.g. practice rooms, rehearsal studios, concerts halls
***How often* do they need to do it?**	Every time noise levels exceeds/are expected to exceed 85dB
***With whom* do they need to do it?**	Alone, with peers, and with teachers/supervisors

Step 4 – Identify what needs to change

In order to effect behaviour change, it is essential to understand and target the barriers to- or facilitators of- the desired behaviour in at least one of the core elements of the COM-B model. Therefore, a crucial aspect of the design of this intervention to increase HPD use in musicians involved collecting qualitative data from early-career musicians relating to their thoughts and opinions about hearing loss and the use of HPDs in order to identify the key barriers and facilitators.

The main barriers and facilitators to HPD use are described in supplementary materials S3 and the assignment of these barriers/facilitators according the COM-B model/TDF is shown in Table 1 of the main manuscript.

Step 5 – Identify intervention functions

Having determined the barriers/facilitators and organised them according to the COM-B/TDF model, the subsequent step is to link the COM-B/TDF components to appropriate intervention functions likely to be effective in evoking behaviour change (see Table 1 in main manuscript). The APEASE criteria is used to identify the most appropriate intervention functions.

Candidate intervention functions	**Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Education – Increasing knowledge or understanding	**Knowledge** (Lack of concern vs. Concern about hearing problems) **- Not effective** as student musicians are more aware of noise induced hearing problems and have healthier attitudes towards hearing conservation than non-musicians (Chesky et al., 2009). Information relating to safe sound levels are almost always provided as part of an educational program on noise exposure (e.g. Wright-Reid and Holland 2008), thus providing more education is unlikely to improve awareness of sound levels, nor alter beliefs about necessity of HPD use. **Behavioural regulation** (Lack of access vs. Ease of access to HPDs) **- Not practicable** to teach forgetting prevention (e.g. remembering to take HPDs with them at the start of the day). **Social/Professional responsibility** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Social pressures) – **Not effective** (see Knowledge). **Beliefs about Capabilities/Consequences** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Discomfort and poor fit) – **Not practicable**. Difficult to educate people about their own beliefs about playing abilities whilst using HPDs (although see Persuasion and Modelling), since the impact on listening and playing abilities, and discomfort and fit, is objective (e.g. Chasin and Chong 1999). Also **not effective** (see Knowledge). **Optimism**; **Goals; Intentions** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems) - **Not practicable** to educate musicians on their priorities, nor to teach them how to not be lazy. Musicians are more aware of benefits of HPD use so further education is **not effective** (Chesky et al., 2009).

Candidate intervention functions	**Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Persuasion – Using communication to induce positive or negative feelings or stimulate action	**Emotion** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems) **– Not practicable** to persuade individuals that HPDs will not impact on their music playing/listening/enjoyment where HPDs objectively have a negative impact (vs. Improved sound quality or enjoyment). Also **not effective** (see Education - Knowledge). **Social/professional responsibility** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Social pressures) **– APEASE met** – Encourage users of HPDs (students and teachers) to persuade others to do so also as part of a musicians' professional standards/identity/duty to themselves and other musicians. **Beliefs about Capabilities/Consequences** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Discomfort and poor fit) – Persuade musicians to use high-fidelity/quality HPDs to prevent impact on music listening/playing/enjoyment, but these are **not affordable** for everyone**,** and thus **not equitable**, plus the majority of participants were already provided with musicians' earplugs through the institute, and so **not effective/cost effective** (see Enablement). **Optimism**; **Goals; Intentions** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems) – **Not effective** since musicians are aware/concerned about the importance of HPDs (see Education – Knowledge), therefore difficult to further persuade musicians to prioritize hearing health.
Incentivisation – Creating an expectation of reward	**Reinforcement; Emotion; Intentions; Goals:** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Social pressures) **All N/A – Not practicable**. Difficult to offer short term rewards for wearing HPDs. The reward is to retain hearing/prevent tinnitus, which musicians are already aware of (see Education). Possible to be more lenient/forgiving of musical errors by early-career student musicians who are trying to play whilst using HPDs (see Training and Enablement).

Candidate intervention functions	**Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Coercion – Creating an expectation of punishment or cost	**Reinforcement; Emotion; Intentions; Goals:** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Social pressures) **All N/A – Not practicable**. As per Incentivisation, musicians are aware of the costs/risks of not using HPDs. Punishment for not using HPDs is **not practicable, not acceptable**, and could pose **side effects** such as opposition or defiance (see Restriction also).
Training – Imparting skills	**Skills** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment) – Encourage students to practice/rehearse using HPDs so that they are used to attenuated sound levels and will have less of an impact on performances, plus will be more used to the sensation (Discomfort and poor fit). However, this might **not be practicable** and/or **not acceptable** for early-career musicians where they are in high-pressure situations and may not be willing/able to offer short-term compromises to their musical abilities. May be best suited to novice or child musicians when beginning to learn an instrument, when the impact of HPDs on music playing may be less costly and more time can be taken to master their instrument while using HPDs. **Memory, Attention and Decision Processes** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs), **Behavioural Regulation** (Lack of access vs. Ease of access to HPDs), **Reinforcement** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Social pressures) – **Not practicable** to impart skills for these barriers (similar to Education). **Environmental context and resources** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs; Discomfort and poor fit; Affordability of high-fidelity HPDs) – **Not practicable** to train awareness of sound levels, especially given changing circumstances for student musicians and dynamic nature of music.

Candidate intervention functions	**Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Restriction – Using rules to reduce the opportunity to engage in the target behavior (or to increase the target behavior by reducing the opportunity to engage in competing behaviours)	**Environmental context and resources** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs; Discomfort and poor fit; Affordability of high-fidelity HPDs) – Enforcing HPD use or placing restrictions on practicing and performing in environments which exceed noise limits if not using HPDs. **Not practicable** to enforce since using HPD use is not mandatory (Control of Noise at Work Regulations, 2005), plus students also practice/perform outside of institution. Also **not equitable** for students who are not at risk. (See also Coercion; **not acceptable** to all students and could pose **side effects** such as opposition or defiance). **Social influences** (Social pressures) – **Not practicable** to use rules to prevent stigma or peer pressure from other students, since this could be an implicit/indirect influence. **Not practicable** and **not acceptable** to prevent interactions between students. Social restriction may develop over time as stigma could be reversed with increased uptake (i.e. change in social norms towards HPD use).

Candidate intervention functions	Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
Environmental restructuring – Changing the physical or social context	**Memory, Attention and Decision Processes** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs) and **Environmental context and resources** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs; Discomfort and poor fit; Affordability of high-fidelity HPDs – **APEASE met** - Provide information (i.e. reminders as opposed to Education) about dangerous/critical sound levels and/or HPD use before and during noise exposure. **Reinforcement** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Social pressures) – see Incentivisation and Coercion – **not practicable**. Possible to provide physical reminders about the risks of noise exposure, but musicians are generally aware/concerned and educated (i.e. **not effective;** see Education). **Social influences** (Social pressures) – **Not practicable** (see Restriction). **Not acceptable** and **not practicable** to isolate or to prevent interactions with students who do not use HPDs or have negative attitudes towards HPDs.
Modelling – Providing an example for people to aspire to or imitate	**Behavioural Regulation** (Lack of access vs. Ease of access to HPDs), **Emotion** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems); **Social influences** (Social pressures); **All Reflective Motivation TDFs** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Social pressures; Discomfort and poor fit) – Role models i.e. teachers, staff members, successful peers/alumni, famous musicians to champion the use of HPDs (see Persuasion). **APEASE met** for early-career musicians. However, potential confounds e.g. **not practicable** and/or **not affordable** to involve highly influential/famous musicians. Possibly **not acceptable** to all staff members, and so **not equitable** for all students, depending on the staff member/teacher.

Enablement – Increasing means/reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring)	**Memory, Attention and Decision Processes**; **Behavioural regulation; Environmental context and resources** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs ; Discomfort and poor fit; Affordability of high-fidelity HPDs) – Provide access to high-fidelity musicians' earplugs in practice rooms/rehearsal studios/performance spaces etc. **Not affordable** to make high fidelity/high quality HPDs readily available. Cheaper reusable non-musicians' earplugs **not acceptable** and **side effects** in terms of impact on music listening/playing/enjoyment. **Emotion**; **Beliefs about capabilities; Optimism**; **Goals**; **Environmental context and resources** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Lack of concern vs. Concern about hearing problems; Lack of access vs. Ease of access to HPDs ; Discomfort and poor fit; Affordability of high-fidelity HPDs) – Providing access to free/reduced price, high quality, musicians' earplugs that do not impact on performances. Very high-quality custom made HPDs are expensive and so **not affordable** for all institutes and therefore **not equitable**, plus they may be no more effective than the non-custom HPDs already provided (Chasin and Chong, 1999)**.** All students are currently provided with reusable non-custom high-fidelity musicians' earplugs (see Persuasion), so providing these does **not provide additional effectiveness/cost-effectiveness**. Although, provision of musicians' earplugs should not be removed as many students do rely on these to protect their hearing. **Emotion; Beliefs about capabilities; Goals; Social influences** (Detrimental vs. No impact of HPDs on music listening/playing/enjoyment; Social pressures) - Reduce pressure on students to give perfect performances and provide more lenient recital scoring if using HPDs. **Not acceptable, not practicable** and potential **side effects** as it could take students longer to master their instrument, which is constrained by their degree length, and students may try to blame HPD use on poor performance to achieve better grades. This suggestion would also require restructuring of current marking schemes which vary for different instruments/genres etc., so is **not acceptable** for students and staff, and **not equitable** across genres/instrument classifications.

Candidate intervention functions	Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
Selected intervention functions:	**Environmental restructuring** – Memory, Attention and Decision Processes; Environmental context and resources **Persuasion/Modelling** – Social/professional responsibility; Social influences; Behavioural regulation; Emotion; Reflective Motivation (all TDFs) – Although see potential APEASE restrictions

Step 6 – Identify policy categories

This stage of the BCW aims to determine policies that would support the delivery of the intervention functions. There are seven policy categories which represent possible actions taken by authorities (e.g. employers, principals, government) to implement interventions; Communication/marketing, Guidelines, Fiscal measures, Regulation, Legislation, Environmental/social planning and Service provision. Each intervention function is linked with various policy categories likely to be effective in supporting the intervention. The APEASE criteria is also used at this stage for selecting the most appropriate policy categories for the intervention functions selected in Step 5.

Intervention function	Policy categories	Does the policy category meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
Persuasion/Modelling	**Communication/marketing**	**APEASE met** – i.e. changing social norms/acceptability through media and print.
	Guidelines	**Not effective** as music students are already educated on NIHL/tinnitus and are aware of best practice for prevention.
	Regulation	**Not practicable** to enforce rules on HPD use in all settings (i.e. personal practice). **Not acceptable** for all and could lead to opposition/defiance (**side effects**).

Intervention function	**Policy categories**	**Does the policy category meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
	Legislation	See regulation. Current legislation **not effective** for improving HPD uptake by musicians (Control of Noise at Work Regulations, 2005). **Not equitable** as legislation does not apply to early-career musicians.
	Service provision	**APEASE met** – i.e. access to hearing health services and support networks
Environmental restructuring	Guidelines	As above
	Fiscal measures	N/A
	Regulation	As above
	Legislation	As above
	Environmental/social planning	**APEASE met** – i.e. designing the physical environment to prompt HPD use

Step 7 – Identify behaviour change techniques (BCTs)

BCTs represent the smallest active ingredients or 'mechanisms' of the intervention assigned to bring about change. Each intervention function is linked with 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 the most suitable BCTs have been systematically selected, this step also involves drafting an intervention strategy designed to bring about the desired behaviour change, describing specifically how these BCTs could be delivered (see main manuscript).

Intervention function	Individual BCTs	Does the BCT meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
Persuasion/Modelling	**Most frequently used BCTs:**	
	- **Credible Source**	- **APEASE met** – verbal or visual communication of HPD use from familiar staff, teachers, influential musicians etc. (although possibly not affordable, practicable, acceptable and equitable for all students – see Step 5 - Intervention Functions).
	- **Information about social and environmental consequences**	- **Not effective.** Musicians are aware of consequences for career.
	- **Information about health consequences**	- **Not effective.** Musicians are aware of health consequences.
	- **Feedback on behavior**	- **Not effective** to provide feedback on amount of HPD use, especially with no immediate benefits (see Feedback on outcome(s) of the behavior)
	- **Feedback on outcome(s) of the behavior**	- **Not practicable** to monitor prevention of hearing loss with HPD use.
	- **Demonstration of the behavior (Modelling)**	- **APEASE met** – staff, teachers, influential musicians etc. to provide an observable example of HPD use (although possibly not affordable, practicable, acceptable and equitable for all students – see Step 5 - Intervention Functions)
	Less frequently used BCTs:	
	- Biofeedback	- **Not effective** and possible **side effects** – regular audiological health check-ups may only prompt HPD

Intervention function	Individual BCTs	Does the BCT meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
		use if hearing problems are detected or may prevent use if hearing problems are not detected. Hearing damage can also be subtle and not easily detectable by standard clinical measures. Use of HPDs will not reverse hearing damage.
	- Focus of past success	- **Not equitable** since not everyone will have used HPDs previously. **Not practicable** as benefits of previous HPD use for hearing health are not easily measurable.
	- Verbal persuasion about capability	- **APEASE met** – providing reassurance about performing and enjoying music whilst using HPDs.
	- Framing/reframing	- **Not practicable** to reframe hearing protection as hearing loss prevention as the terms are used indiscriminately, plus HPDs only serve a single purpose.
	- Identity associated with changed behavior	- **Not practicable.** No strong identity associated with being a HPD user/non-user.
	- Identification of self as role model	- **APEASE met – ** changing social norms/acceptability and encourage students to act as role models for peers.
	- Informational about emotional consequences	- **Not effective**. Students already aware of hearing/career longevity, and thus mental wellbeing.
	- Salience of consequences	- **Not effective.** Students already aware/educated.

Intervention function	Individual BCTs	Does the BCT meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
	- Information about others' approval - Social comparison	- **APEASE met** - inform students that peers, staff, teachers, employers, etc., approve of HPD use/are not disapproving of HPD use. - **APEASE met** – compare behaviour to peers, staff, teachers, influential musicians etc., who use HPDs.
Environmental restructuring	**Most frequently used BCTs:** - **Adding objects to the environment** - **Prompts/cues** - **Restructuring the physical environment**	- **Not effective/cost-effective.** Students already provided with high fidelity musicians' HPDs. **Not affordable** to provide free and unlimited access to high fidelity HPDs, nor to provide custom moulded HPDs to all musicians. Low quality HPDs are **not effective** in the musical setting. - **APEASE met** – i.e. signage to inform students that they are entering a loud environment and/or sound level meters with visual display to provide read out of sound levels/noise limits. Calendar/push notifications to inform or remind students about upcoming loud rehearsals/performances (also linked to BCT **Action planning –** encourage students to plan to carry HPDs when going to noisy rehearsals). - **APEASE met** - Advise students to keep HPDs on their person at all

Intervention function	Individual BCTs	Does the BCT meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
		times (i.e. in their instrument case) to ensure easy access. Can be reminded within **Prompts/cues**.
	Less frequently used BCTs:	
	- Cue signalling reward	- **N/A.** No short-term reward associated with HPD use.
	- Remove access to the reward	- **N/A.** No short-term reward associated with HPD use.
	- Remove aversive stimulus	- **N/A.** No aversive stimuli associated with preventing HPD use.
	- Satiation	- **Not practicable**
	- Exposure	- **APEASE met** - Advise students to use HPDs in different contexts (i.e. quiet and loud) so that they get used to impact of HPDs on music listening/performing in a variety of settings (link to BCTs **Behavioural practice/rehearsal** and **Habit formation**).
	- Associative learning	- **N/A.** Cannot use positive/negative reinforcement for HPD use as no short-term rewards. Students already aware of association between noise exposure and hearing problems, so **not effective**.
	- Reduce prompt/cue	- **Not effective** to remove the useful prompts/cues.
	- Restructuring the social environment	- **Not practicable** and **not acceptable** to isolate different groups of students socially based on HPD use and attitudes to HPD use.
Intervention function		

Intervention function	Individual BCTs	Does the BCT meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
- Persuasion/Modelling - **Credible Source; Demonstration of the behavior (Modelling);** Verbal persuasion about capability; Identification of self as role model; Information about others' approval; Social comparison - Environmental restructuring - **Prompts/cues; Restructuring the physical environment;** Exposure		

Step 8 – Identify mode of delivery

This final step of the BCW aims to identify how the selected BCT(s) and intervention strategy will be delivered, such as face-to-face methods at the group or individual level, or via distance methods at the population or individual level. The possible modes of delivery are also assessed according to the APEASE criteria.

<u>Persuasion/Modelling</u> **Mode of delivery**				**Does the mode of delivery meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Face-to-face	**Individual**			**APEASE met**
	Group			**APEASE met**
Distance	**Population-level**	**Broadcast media**	**TV**	Not relevant for delivering BCTs relating to Persuasion/Modelling since these mostly require direct interaction with another person (e.g. staff/teacher/peers) within the musical institute.
			Radio	
		Digital media	**Internet**	
			Mobile phone app	
		Print media	**Newspaper**	
			Leaflet	
			Billboard	

		Outdoor media	**Poster**	
	Individual-level	**Phone**	**Phone helpline**	
			Mobile phone text	
		Individually accessed computer programme		

<u>Environmental restructuring</u> **Mode of delivery**				**Does the mode of delivery meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?**
Face-to-face	**Individual**			**APEASE met (verbal/visual prompts/cues)**
	Group			**APEASE met (verbal/visual prompts/cues)**
Distance	**Population-level**	**Broadcast media**	**TV**	Not practicable; not cost-effective; not equitable
			Radio	Not practicable; not cost-effective; not equitable
		Digital media	**Internet**	Not practicable; not equitable
			Mobile phone app	Not practicable; not equitable
		Print media	**Newspaper**	Not cost-effective and not equitable
			Leaflet	Not cost-effective
		Outdoor media	**Billboard**	Not cost-effective

			Poster	**APEASE met**
	Individual-level	**Phone**	**Phone helpline**	N/A
			Mobile phone text	**APEASE met**
		Individually accessed computer programme		**APEASE met**

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S3. Identifying barriers and facilitators to HPD use

Barriers to HPD use

Detrimental impact of HPDs on music listening/playing/enjoyment

Consistent with previous research (e.g. Laitinen 2005), early-career musicians indicated that wearing HPDs impacts on musical listening and playing abilities, such as the ability to hear their own instruments or others around them, or reduce the enjoyment of the music:

> "*The only downside is that if you do wear earplugs, sometimes it's difficult to hear. If you're playing an ensemble it's difficult to hear other people. Sometimes it's difficult to hear if you're playing in tune or not*." – Participant 5 – Saxophonist

These opinions were based on either personal experience of using HPDs or beliefs/expectations about using HPDs. Irrespective, it has been shown that even 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 (Kozłowski et al., 2011) and less resonant choral singing (Cook-Cunningham, 2019).

Due to the impact of HPDs on music playing, participants also suggested that the context of the music playing could influence whether they use hearing protection or not. For example, musicians may be comfortable using hearing protection during personal practice and rehearsals where the cost of making mistakes is low, but not for performances where mistakes may be less acceptable. This may also explain the different HPD use patterns for different musical activities (see Fig. 1c in manuscript):

> "*It's different when it's in an orchestra, it's not as important listening to your own sound but when you're on your own you can't really compromise on what you can hear, you can't block your ears*." – Participant 7 – Violinist

> "*Well, it's mainly the difficulty of the music and whether it will impact or impair my ability to play the music as well as I possibly can. Often with session music or music where there's a band, the string parts are usually easier and they can't hear you as well so it doesn't fuss me that I can't hear it*." – Participant 57 - Violinist

Participants also mentioned compromising between protecting their ears and being able to perform to a high standard, especially in certain musical settings.

> "*I think it's really important to protect your hearing but then, at the same time, if you've got to balance that with actually performing to your best ability as well*." – Participant 48 - Trumpet player

For certain early-career musicians, they are willing to sacrifice performance and listening quality for the sake of protecting their hearing (see Facilitators – Concerns about developing hearing problems).

> "*I think that it should be encouraged and I think people should do it more because it's more important to have your hearing than to feel fully immersed in music, I think*." – Participant 74 - Saxophonist

On the contrary, other early-career musicians are not willing to sacrifice performance quality to protect their hearing.

> "*…it's quite tough to wear ear protection because I just can't hear what I'm doing and I'd rather do a good job than save myself some trouble in 30 years*." – Participant 18 - Cellist

Lack of concern about hearing problems

A general lack of concern about NIHL and using HPDs stems from several different factors. First, early-career musicians indicated that HPDs may not be necessary for their instrument type, genre or a particular environment:

> "*I think it depends which genre of music we are in. So, for example, I'm in the classical sort of genre, so it's generally not as bad compared to the pop and rock sort of genre*." – Participant 14 - Pianist

While this may be true in certain circumstances, there is evidence to suggest that 74% of music students exceed the recommended daily exposure limits (see NIOSH, 1998) on three or more days of the week, compared with just 13% of non-musicians (Tufts and Skoe, 2018). Additionally, Phillips and Mace (2008) suggested that 48% of music students exceed allowable sound exposure levels from individual practice alone. Accordingly, the belief that HPDs are not warranted might be ill-conceived and could indicate a lack of awareness of potentially damaging noise levels:

> "*…as a pianist, you don't actually realise how loud the piano is. When you're in somebody's room and they're practising, you realise how loud it actually is, but when you're practising yourself it's not that obvious*." – Participant 10 - Pianist

Second, early-career musicians indicated that HPD use was low priority, where focussing on the performance at hand or other health-related issues were a more pressing concern:

"*It's something that we worry about but it would be further down the list of priorities compared to, like, tendonitis and muscular problems and everything that obviously stop you playing completely*." – Participant 7 - Violinist

"*I think when gigging, especially, it's obviously a high stress situation of setting everything up, and when you're ready the last thing I'd think to do would be to put my earplugs in*." – Participant 64 – Pianist

Focussing attention and priorities elsewhere could also explain why early-career musicians reported that they forget to use HPDs or why HPD use is not automatic:

"*I think most of the times I don't really use it because I just forget*…" – Participant 54 - Tuba player

"*I do have hearing protection and I need to wear it more because they are nice and it would be really good for me just to wear them without thinking about it*." – Participant 51 - Viola player

Third, a lack of concern about NIHL could stem from a lack of experience of hearing problems, either personally or anecdotally, and so early-career musicians may feel less need to protect their hearing:

"*I think there's always a sort of thing where you go to something and then you're fine afterwards then you kind of assume you'll be fine the next time and the next time and the next time, which may not necessarily be the healthiest of attitudes*…" – Participant 50 - Pianist

"*We're worried about it for future problems when we're more into our career but, for now, I think we're okay. We're not suffering from it yet, so it's not a major problem*." – Participant 76 - Clarinet player

Indeed, previous research suggests that musicians are more likely to use HPDs if they have an existing hearing problem (Greasley et al., 2018; Laitinen, 2005; Laitinen and Poulsen, 2008; O'Brien et al., 2014)

Finally, a lack of concern could be due to a lack of knowledge and awareness about noise induced hearing loss:

"*I guess it would concern people more if we knew more about the real consequences…*" – Participant 13 – Pianist

A lack of education could also lead to the false belief that noise-induced hearing problems are an inevitable consequence of the music profession that cannot be prevented effectively. This sense of

hopelessness could mean that early-career musicians do not see the point of using HPDs to protect their hearing:

> "*I think some of my friends don't use hearing protection, they kind of have the mind-set of, it'll just happen anyway because I'm a musician and I play percussion, or I play a loud instrument*..." – Participant 58 - Percussionist

> "*I think it's something that I think as a musician you kind of have in the back of your mind just in the sort of way that any negative eventuality is*." – Participant 50 - Pianist

Social pressures (Barrier)

Early-career musicians provided evidence for a range of social pressures which could prevent HPD use. First, noise-induced hearing problems and HPD use might be considered a taboo topic of conversation amongst musicians:

> "*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

Second, early-career musicians were concerned about social stigma or judgment from friends, peers and/or employees if they wore hearing protection:

> "*I feel like I wouldn't be asked back if I was going to put earplugs in while I was rehearsing or in a concert*." – Participant 52 - Viola player

Third, there were also concerns about aesthetics and being perceived to have weak or damaged hearing:

> "*Sometimes I think that you see hearing protection and they can, say, look like somebody's wearing a hearing aid or something, so therefore I think there's quite a negative view of it. It's just with, I think, younger people and the way it looks mainly. That's just a stigma that needs to be overcome…*" – Participant 35 - Voice

Finally, colleagues, teachers and/or institutes might not provide enough encouragement and support to use HPDs:

> "*I think it would be important for universities and colleges to promote it more because I've never really heard of it from the university or my teacher, anyone like that. I think it's important that you make students aware that they need to be protected in their ears because all I've ever heard it from is my parents*." – Participant 51 - Trombone player

Lack of access to HPDs

The availability of HPDs was also a problem for early-career musicians, where these were not always to hand during loud performances:

> "*I always keep meaning to buy some earplugs or something so that I do have them around for when I would be in a situation that it would be good to have them but I just haven't got round to doing it yet*." – Participant 50 - Pianist

There are several bad habits that contributed to a lack of access to HPDs. For example, poor planning or a lack of routine meant that musicians forgot to take HPDs with them when leaving home, or did not have them about their person at crucial times:

> "*… it's not something that's at the forefront of my mind to just go, wait, let me just grab that*." – Participant 35 - Voice

Alternatively, early-career musicians also attributed non-use of HPDs to their own laziness and inaction to acquire HPDs:

> "*More just out of being lazy and not going to a shop to buy some*." – Participant 64 – Pianist

Note that part of the Royal Northern College of Music's strategy to promote healthy hearing behaviours involves providing all students with high-fidelity non-custom musicians' earplugs. Accordingly, the majority of early-career musicians in this study should have access to HPDs, unless these have been lost or forgotten.

Discomfort and poor fit

Dislike of the physical sensation of HPDs in the ears or problems with fit and placement is an issue for some early-career musicians, as has been reported in previous research (e.g. Patel 2008). This included HPDs being painful whilst trying to insert or whilst in place, or not being able to get used to the feeling of HPDs despite perseverance.

> "*…sometimes they're uncomfortable, they're a bit of a pain to get in and out…"* – Participant 56 - Tuba player

Affordability of high-fidelity HPDs

Early-career musicians indicated that they would use HPDs more if they could afford to buy high-quality/fidelity earplugs that do not have an impact on their music listening and performance:

"*…if there was a better solution for protecting my hearing I'd probably go for it, but it'd have to be sensibly priced and not affect my performance*…" – Participant 23 -Tuba player

"*The moulded ones are something that I've Googled a few times but never actually bought, I think they're quite expensive…"* – Participant 52 - Viola player

"*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

Facilitators of HPD use

Concern about hearing problems

As opposed to a lack of concern about NIHL and tinnitus, early-career musicians suggested that they were worried about developing hearing problems due to noise exposure, and wear - or consider wearing - HPDs to preserve hearing and career longevity:

"*…we only get one 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

"*… you can always put your earplugs in, it's a personal choice. At the end of the day, if your hearing gets damaged, it's your fault, really, so you can't blame someone else for not wearing earplugs*." – Participant 48 - Trumpet player

Having awareness of noisy musical settings that warrant HPD use (either before or during the noisy activity) increases concerns about hearing damage and encourages early-career musicians to use HPDs whenever required:

"*The last time I did I was playing in an orchestra that had loads of guitars and drums and just a lot of loud noise going on all the time, and so I was using hearing protection*." – Participant 18 - Cellist

"*Very rarely, but I think there have been occasions where some volumes of music have stirred out a response to do with hearing loss and, yeah, those occasions are probably the only ones that I can think about that really sort of trigger a response*…" – Participant 62 - Saxophonist

Concerns or awareness of noise-induced hearing problems also implies that early-career musicians have knowledge of the possible detrimental effects of noise exposure. Indeed, early-career musicians

reported being educated about the risks of noise exposure and how to prevent hearing problems, but also indicated that education could have been provided at a younger age:

> "*… in the first week of getting to uni, we had all these talks about protecting hearing. I realised at that point that I'd been part of rehearsals and concerts that were way too loud and it was hours and hours' worth of it*." – Participant 38 – Flautist

> "*I think it's something that we should be made aware of sooner. I was at the Junior Conservatoire for six years and hadn't heard anything about hearing loss or anything related to being a musician, to do with hearing, until I went to the senior department. So maybe it's something that could be introduced a bit earlier on to get into the habit of using hearing protection*." – Participant 71 - Violinist

Nevertheless, knowledge about noise-induced hearing problems does not necessarily mean that musicians are worried about it. Similarly, awareness or concern about the dangers of noise exposure does not necessarily translate into HPD use by early-career musicians:

> "*I think everyone kind of realises that it's a problem but people don't necessarily do anything, or it's difficult to do something about it."* – Participant 78 - Violinist

> "*I think every musician, all of my friends, are terrified of it as it's the thing they want to do as their career, but none of them act upon it*." – Participant 64 - Voice

Social pressures (Facilitator)

Contrary to social pressures which may prevent HPD use, it was also suggested that they could promote HPD use. For example, encouragement to use HPDs from friends, family, peers and teachers:

> "*I know that's something that me and my colleagues and friends have talked about and agreed with, and my parents as well are also urging me to wear it as much as possible, because my mum's a musician and she knows how important it is to protect my hearing*." – Participant 51 - Trombone player

> "*I think it's good that at the Royal Northern now we're being encouraged to use hearing protection and we're being taught about hearing loss*." – Participant 74 – Saxophonist

In addition, it was suggested that HPDs are becoming more normalised and socially accepted with less stigma attached:

"*I think it's becoming quite common now. No one has an issue about it, people just do it*." – Participant 2 - Voice

"*…if I see someone else that is wearing it, then that's sort of a good feeling*." – Participant 15 - Cellist

"*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

Ease of access to HPDs

Since all RNCM students are provided with musicians' earplugs when they enrol on the course, HPDs were readily accessible for participants in the current study.

"*We had a seminar at the very start of first year about how to keep our ears safe…They gave us all proper earplugs and they taught us about tinnitus and things*." – Participant 44 - Voice

These earplugs come in a portable carry container that can be attached to other items, and so may prevent forgetting and ensure ease of access. However, additional strategies were suggested to ensure that HPDs were available whenever they are needed:

"*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

No impact of HPDs on music listening/playing/enjoyment

Participants suggested that they use – or are more likely to use – high-fidelity musicians' earplugs, especially if they do not affect music listening and playing. Despite all RNCM students being provided with high-fidelity musicians' earplugs, participants suggested that they would prefer "up-market" custom-moulded musicians' earplugs:

"*I have the sort of mentality where, if it's not the very best hearing protection, then I'm probably not going to take it as seriously*. *I've had the disposable ones and I've had higher quality ones but they're not personalised, they're not the moulded ones*." – Participant 52 - Viola player

Contrary to the potential for HPDs to impact on music performance and enjoyment, early-career musicians may be capable of getting used to the attenuated sound levels after some perseverance, and music performance abilities might not be detrimentally affected:

"*I think it's quite easy to get used to wearing hearing protection and still play within an ensemble or play on your own and still get used to the sound*." – Participant 58 - Percussionist

Moreover, it was suggested that HPDs may actually *improve* the ability to hear and enjoyment of music, especially in very loud environments and in some musical settings. This could also explain the varying patterns of HPD use for different circumstances (e.g. recreational use; see Fig 1c in manuscript).

"*…let's say I'm at a rock concert, I would use them just because I think you can hear more things if you have earplugs inside your ears because if the concert is really loud then it's kind of hard to hear all the individual parts, so it's actually easier to hear the music with the earplugs in your ears*." – Participant 29 – Classical guitarist

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