

Application of the Behavior Change Wheel within the context of internet-based cognitive behavioral therapy for tinnitus management

Short title: Application of Behavior Change for tinnitus

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Abstract

Purpose: Although experiencing tinnitus can lead to many difficulties, these can be reduced by using techniques derived from cognitive behavioral therapy. Internet-based cognitive behavioral therapy (ICBT) intervention has been developed to provide an accessible intervention. The aim of this study was to describe how ICBT can facilitate tinnitus management by identifying the active ingredients of the intervention from the perspective of health behavior change.

Method: The ICBT intervention was evaluated using the Behavior Change Wheel in eight steps across the following three stages: (1) understanding the behavior, (2) identifying intervention options, and (3) identifying content and implementation options.

Results: Target behaviors identified to reduce tinnitus distress, as well as additional problems associated with tinnitus, included goal setting, an increased understanding of tinnitus, encouraging deep breathing and progressive muscle relaxation, identifying and restructuring unhelpful thoughts, engaging in positive imagery, and reducing avoidance behaviors. ICBT provided the required components for individuals to be physically and psychologically capable of adapting to tinnitus, providing social and environmental opportunities to manage hearing loss through practice and training, and facilitated automatic and reflective motivation.

Conclusions: Understanding the ICBT in the context of the Behavior Change Wheel has helped identify how its effectiveness can be improved and can be used for future tinnitus intervention planning.

Key Words

Tinnitus, Internet intervention, Cognitive behavioral therapy, Intervention design, COM-B model, Behavior change, Behavior Change Wheel

Abbreviations

APEASE: Affordability, Practicability, Effectiveness/cost-effectiveness, Acceptability, Side effects/safety and Equity

BCT: Behavior change technique

BCW: Behavior change wheel

CBT: Cognitive Behavioral Therapy

EMA: Ecological Momentary Assessment

HBM: Health belief model

ICBT: Internet-based Cognitive Behavioral Therapy

NICE: National Institute for Health and Care Excellence

TDF: Theoretical domains framework

TPB: Theory of planned behavior

TTM: Trans-theoretical model

Introduction

Individuals react differently to the onset of tinnitus, defined as the perception of sounds that are not attributed to any external sound sources. Although the majority of individuals are not bothered by these sounds, some individuals are unsure of the cause of tinnitus which results in worrying thoughts (McKenna et al., 2014). For those with troublesome tinnitus it can also cause associated difficulties with sleep, concentration, and hearing (Beukes et al., 2018a; Watts et al., 2018) and psychological effects, such as anxiety and/or depression (Trevis et al., 2018). In an attempt to mitigate these negative effects, some people with bothersome tinnitus use safety and avoidance behaviors, such as avoiding going out to certain places in fear of aggravating the tinnitus (Manchaiah et al., 2018).

To address maladaptive behaviors associated with tinnitus, numerous interventions have been proposed, including medical, psychological, and sound-based approaches, with varying levels of success (Zenner et al., 2017). Due to the demand for cost- and clinically-effective evidence-based healthcare provision (Doi et al., 2017), interventions with clear theoretical behavior change underpinnings have been recommended by practice guidelines, such as United Kingdom's (UK's) National Institute for Health and Care Excellence (NICE) (Lewis et al., 2020). One intervention with a strong theoretical basis is cognitive behavioral therapy (CBT) for tinnitus, which involves several behavioral, cognitive, psychological, and educational components. Although CBT is the intervention with the most research evidence of effectiveness for reducing tinnitus distress (Fuller et al., 2020; Landry et al., 2020), it is seldom provided, partly due to a shortage of professionals with the expertise to provide CBT for tinnitus (Bhatt et al., 2016; Henry et al., 2019). To increase accessibility, an internet-based CBT (ICBT) intervention has been developed (Andersson et al., 2002), and its efficacy has been affirmed in clinical trials conducted in different countries (see Beukes et al., 2019 for a

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review). Nevertheless, the active ingredients of ICBT that lead to behavioral change are not clearly understood (Beukes et al. 2021). Understanding behavior change is complex and challenging and requires the application of appropriate evidence and theory (Campbell et al., 2000; Craig et al., 2008). Identifying the relevant conceptual models of behavior change within ICBT may lead to a better understanding of the active ingredients that need to be targeted, as well as how they can further facilitate behavior change. To achieve this, a systematic approach and explicit rationale should be adopted.

Various models have been developed to understand health behavior change, including the Health Belief Model (HBM; Janz & Becker, 1984), the Theory of Planned Behavior (TPB; Ajzen, 1985), and the trans-theoretical model (TTM; Prochaska & DiClemente, 1983). However, these models are focused on behavioral analysis of health-related problems and have been criticized for not adequately explaining variations in complex human behavior (Coulson et al., 2016). More recently, the Behavior Change Wheel (BCW; Michie et al., 2011) was developed following a synthesis of 19 frameworks of behavior change (Michie et al., 2014). The importance of applying the BCW has been outlined for hearing loss (e.g., Barker, Atkins, de Luignas, 2016; Coulson et al., 2016; Ekberg et al., 2020; Ferguson, et al., 2019, Maidment et al., 2020; Nickbakht, et al., 2020) and tinnitus interventions (Greenwell et al., 2021). Furthermore, it is advocated that such a theory-driven approach should be employed in the development and evaluation of digital health interventions to ensure that they meet the specific needs of the end users and are more likely to result in behavior change (NICE, 2020). Thus, the aim of this paper was to systematically evaluate an ICBT intervention in the context of the BCW to understand how/why the intervention works, as well as how its effectiveness might be improved further.

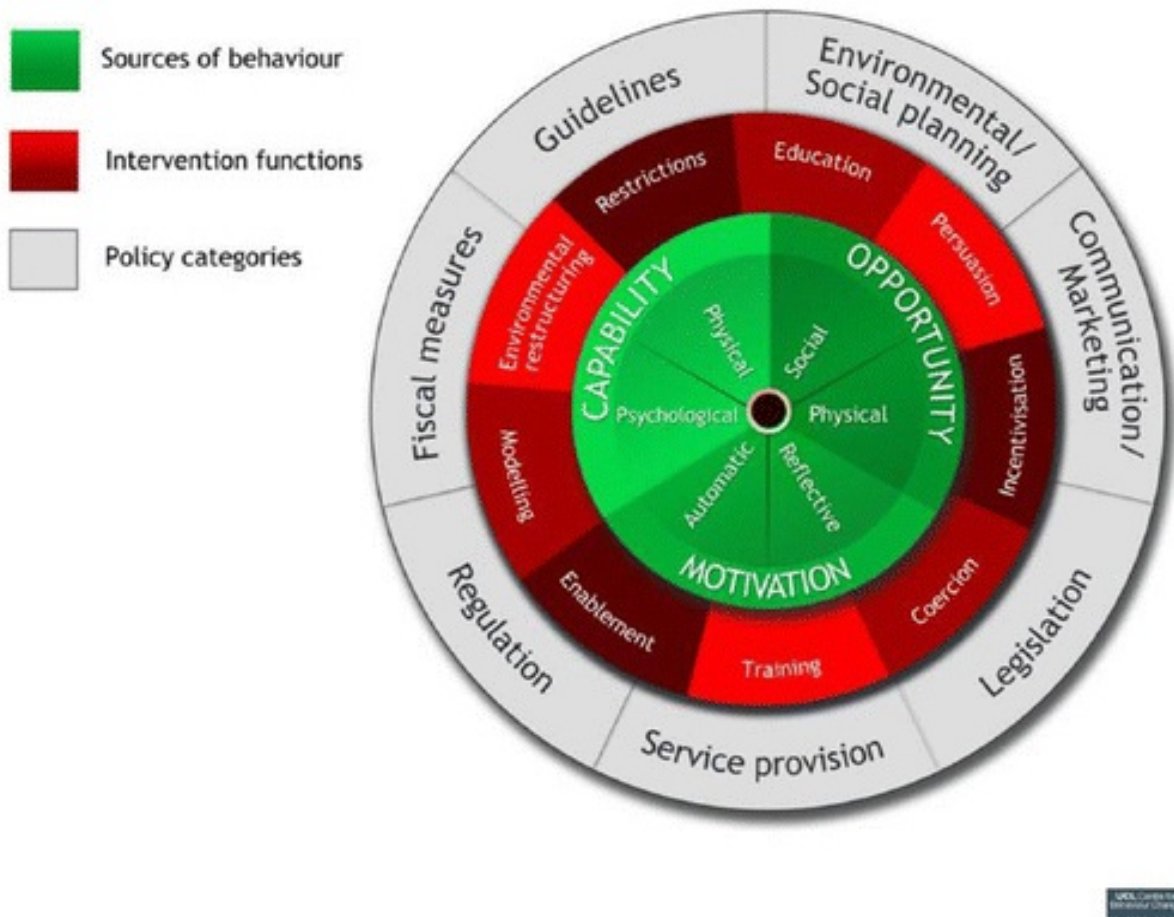


Figure 1. The Behavioral Change wheel. Source: Michie et al., 2011. DOI:

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Methods

Study Design

The study mapped the ICBT intervention for tinnitus to an integrative theoretical framework for behavioral change, namely, the BCW. A team was identified with the needed clinical and research expertise by including interdisciplinary professions with expertise in the areas of CBT for tinnitus and the BCW.

The Intervention Being Evaluated

The ICBT for tinnitus intervention evaluated has a strong theoretical base. It is founded on a cognitive rationale (Henry & Wilson, 2001) and a learning theory approach (Hallam et al., 1984). Following an initial in-person (or face-to-face) version (Scott et al., 1985), the program was developed for a Swedish population in the late 1990's (Kaldo & Andersson, 2004), and the first randomized controlled trial (RCT) using the materials in an online study found encouraging results (Andersson et al., 2002). The materials were frequently updated by Andersson and Kaldo-Sandstrom (2003) and Kaldo et al. (2007). The program was then translated into English (Abbott et al., 2009), German (Jasper et al., 2014), and Spanish (Beukes et al., 2020a) and underwent further updating, although the main components have remained the same (e.g., Beukes et al., 2016; Manchaiah et al., 2020).

The intervention materials are comprehensive, consisting of 22 modules which were developed by input from psychologists, audiologists, and individuals with tinnitus from across the globe. The content promotes altering unhelpful reactions to tinnitus and, identifies and targets factors that slow down progress. It incorporates both audiological and psychological principles, combining expertise from both disciplines to provide individuals with different perspectives on managing their tinnitus. The program has continually evolved to improve its accessibility by ensuring that the readability levels are low and the navigational and usability aspects are not difficult for users (e.g., Andersson & Kaldo, 2006; Beukes et al., 2020; Manchaiah et al., 2020). This intervention has been empirically tested by more than 2,000 individuals with tinnitus. The pooled evidence of several controlled trials indicates undertaking ICBT reduced tinnitus distress, anxiety, depression, insomnia, and quality of life compared with both inactive and active controls (Beukes et al., 2019). It has furthermore been used in clinical settings for more than 20 years (Kaldo et al., 2013).

Evaluation of Behavior Change

To systematically evaluate the mechanisms of action (or active ingredients) of the ICBT intervention that facilitate behavior change, the BCW was selected as the underpinning theoretical approach. The BCW consists of three layers; at the core of the wheel is a model of behavior known as capability, opportunity, motivation, and behavior (COM-B). The model recognizes that behavior (B) is part of an interacting system that involves physical and psychological capability (C), social and physical opportunity (O), and reflective and automatic motivation (M). Critically, the COM-B model can be used to identify which of these components need to change to facilitate a target behavior. Surrounding the COM-B model is a layer of nine intervention functions (education, persuasion, incentivization, coercion, training, restriction, environmental restructuring, modelling, enablement), which can be selected to change behavior. The outer layer of the BCW identifies seven policy categories (communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning, service provision) that can be adopted to deliver the intervention.

When using the BCW to develop and evaluate health behavior change interventions, it is recommended that the following three stages, which are divided into eight separate steps, are followed (Michie et al., 2014): Stage one (steps 1-4) is concerned with understanding the behavior and includes the COM-B model (step 4), whereas in stage two (steps 5 and 6) and three (steps 7 and 8) intervention and content/implementation options are identified, respectively. For ease of understanding, all stages and steps are outlined in detail within corresponding sub-sections in the results section.

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Conceptually implementing behavioral changes into the intervention

An Implementation Research Logic Model was used to illustrate how these behavioral changes identified are conceptually implemented into the intervention (Smith, Dennis & Rafferty, 2020). This provides a framework to organize the links between the theoretical domains and the intervention to aid future developments and implementation.

Results

Stage 1: Understanding the Behavior

To understand the problem to address in behavioral terms, *what the behavior is, who is performing the behavior, and what behaviors are required for behavior change* were identified in a four-step process outlined below.

Step 1. Define the Problem in Behavioral Terms

An open-ended survey questionnaire was used to identify problems associated with tinnitus from 240 individuals with tinnitus asking them to describe situations where tinnitus was a problem (see Beukes et al., 2018a). A second question was asked regarding managing the problems. This information was used to define tinnitus in behavioral terms as: *how to improve successful management of tinnitus, resulting in reducing tinnitus related distress* (Worksheet 1 in Supplemental Materials 1). Individuals with tinnitus explained that problems with tinnitus generally occur in a range of contexts, including quiet or noisy situations, being alone, when concentrating, or when sleeping (Beukes et al., 2018a). Thus, the location (or context) of the problem was defined as any context to include when sleeping, in quiet and when feeling anxious. Professionals and support systems can guide behavior change, but it is the individual experiencing bothersome tinnitus that needs to be actively involved in performing the behaviors required to improve reactions toward tinnitus.

Step 2. Select the Target Behavior

The research team generated a ‘long-list’ of candidate behaviors relevant to the problem behavior identified in step one that could bring about the desired outcome (i.e., improve successful management of tinnitus, resulting in habituation) (Worksheet 2a in Supplemental Materials 2). These behaviors were derived from literature outlining the relationship between tinnitus and psychological distress (Andersson, 2002), and reports regarding problems associated with tinnitus (e.g., Beukes et al., 2018a; Watts et al., 2018). Previous studies have shown that many problems and life effects experienced by those with tinnitus are related to behaviors surrounding activity limitations (disability), and participation restrictions (handicap) (Manchaiah et al., 2018), which should be addressed. The target behaviors were then prioritized by considering the: (i) *likely impact of changing the behavior*; (ii) *likelihood of changing behavior*; (iii) *spill-over or impact of change on other behaviors*; and (iv) *ease by which the behavior could be measured or monitored* (Worksheet 2b in Supplemental Materials 3). For each potential target behavior, the research team rated each criterion as *very promising*, *promising*, *unpromising but worth considering*, or *unacceptable* as a behavior to be targeted.

The target behaviors chosen to address the behavioral problem were those that were likely to make an impact if the behavior was changed. These included goal setting, an increased understanding of tinnitus, encouraging deep breathing and progressive muscle relaxation, identifying and restructuring unhelpful thoughts, engaging in positive imagery, reducing avoidance behaviors, behavioral activation, increased problem-solving abilities, attention control, altering behaviors to improve sleep, the ability to listen to tinnitus, and engaging in monitoring progress (Figure 2). These behaviors were furthermore selected as they can

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change behaviors that may impact on other difficulties associated with tinnitus, such as managing sleep problems, stress, and anxiety. In the ICBT intervention, monitoring of these behaviors was enabled by the availability of worksheets and patient diaries, where individuals could note how frequently and successfully these strategies were applied.

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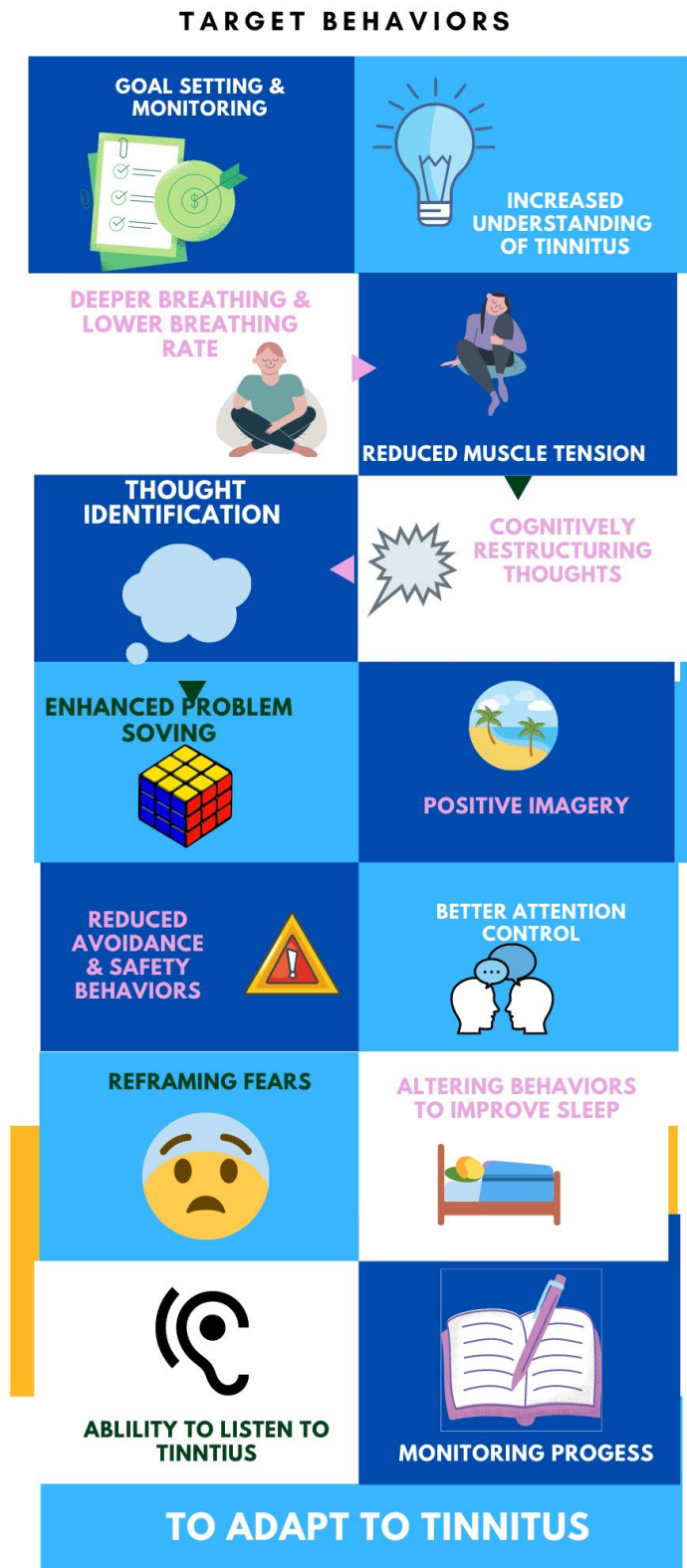


Figure 2. Target behaviors identified to adapt to tinnitus.

Step 3. Specify the Target Behavior.

The target behaviors were then further specified by detailing *who needed to do what, when, where, how often, and with whom* (Worksheet 3 in Supplemental Materials 4). As the ICBT intervention is a self-help program with minimal guidance from a clinician, the target behaviors are directed at the individual with tinnitus using the intervention materials available to them independently.

Step 4. Identify what needs to change.

The COM-B model was applied to identify what needed to change in the person and/or environment to achieve the desired change in behavior (i.e., reacting adaptively to tinnitus). This step was based on the clinical and research experience of the research team as well as findings from relevant literature (e.g., Andersson, 2002). Overall, we identified that changes needed to occur in all COM-B components for the target behavior to occur as follows (see also, Worksheet 4, in Supplemental Materials 5):

- Capability:
 - Physical capability (skills, strength, or stamina), which, in this context, is engaging in deep breathing and progressive muscle relaxation.
 - Psychological capability (knowledge, psychological skills, strength, or mental stamina), which includes identifying and reducing negative thoughts and emotions related to tinnitus.
- Opportunity:
 - Physical opportunity (what the environment allows or facilitates in terms of time, triggers, resources, etc.), which includes creating time to engage with the ICBT intervention and having reminders and prompts.

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- Social opportunity (e.g., interpersonal influences, social cues, cultural norms), such as support from friends and family to undertake the intervention.
- Motivation:
 - Reflective (involving self-conscious planning and evaluations), such as believing that engaging in the target behavior will result in positive outcomes.
 - Automatic (processes involving needs, desires, impulses, and reflex responses), which includes goals setting and monitoring and completing weekly diaries.

Stage 2: Identify Intervention Options

Step 5. Intervention Functions

Based on the results of the COM-B analysis in step four, suitable intervention functions were chosen for each of the target behaviors. To decide which of the intervention functions were the most appropriate, the Affordability, Practicability, Effectiveness/cost-effectiveness, Acceptability, Side effects/safety and Equity (APEASE) criteria were applied. Judgements were based on the clinical and research experience of the research team. As outlined below and in Worksheet 5 (Supplementary materials 6), education, persuasion, incentivization, coercion, training, modeling, and enablement were all selected as suitable intervention functions to facilitate the target behavior. The remaining intervention functions of restriction and environmental restructuring were considered impractical in the current context.

Specifically, to address physical (i.e., have better physical skills) and psychological (i.e., increasing knowledge, cognitive skills, mental strength, and sustained resistance) capability, *education, training, and modelling* were identified as the most appropriate intervention

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functions. *Training* (i.e., create more time for the intervention and have cues or prompts as practice reminders) and *restriction* (i.e., identifying unhelpful behaviors and thought patterns), were chosen to address aspects of physical opportunity, whereas *modelling* (i.e., increase social support from friend and family and others with tinnitus), and *restriction* (i.e., opportunity restrict avoidance behaviors) were chosen as the best intervention functions to address social opportunity. For reflective motivation (i.e., positive beliefs), *education*, *persuasion*, *incentivization*, *coercion*, *modelling*, and *enablement* were all identified as suitable intervention functions. Finally, *training*, *modelling*, *environmental restructuring*, and *enablement* were identified as the most suitable intervention functions to address automatic motivation (i.e., establishing a routine or habit).

Step 6. Policy Categories

The policies that could support the delivery of the intervention functions identified in step five were also considered in relation to the APEASE criteria. The following policy categories were identified: communication/marketing, guidelines, fiscal measures, regulation, legislation, environment/social planning, and service provision (Worksheet 6 in Supplementary materials 7). The policy categories that were rated as most suitable for supporting and enacting the intervention were the creation of suitable guidelines (e.g., producing and disseminating treatment protocols) and service provision (e.g., establishing ICBT in different contexts and communities). However, as the intervention was not widely disseminated, other categories could be applicable in the long-term, although not at present.

Stage 3: Identify Content and Implementation Options

Step 7. Behavior Change Techniques

Having identified the intervention functions in step five, and policy categories in step six, the next step identified intervention content in terms of behavior change techniques (BCTs) that can best deliver the intervention functions (see also, Table 1). Most frequently used BCTs were derived from the BCT Taxonomy v1 (BCTTv1), which includes 93 BCTs organized into 16 groupings (Michie et al., 2013).

Suitable BCTs identified, based in intervention functions selected in Step 5, are outlined in Worksheet 7 (Supplemental Materials 8). For the education intervention function, the most appropriate and frequently used BCTs are *information about social and environmental consequences, information about health consequences, prompts/cues, and self-monitoring of behavior*. Within persuasion, selected BCTs were *credible source, information about social and environmental consequences, and information about health consequences*. To address incentivization and coercion, *self-monitoring* was considered the most suitable BCT. For training, selected BCTs were *demonstration of the behavior, instruction on how to perform behavior, self-monitoring of behavior, and behavioral practice rehearsal*. For the modelling intervention function, *demonstration of the behavior* was also viewed as being effective in this context. Finally, to address enablement, appropriate BCTs were *social support (unspecified/practical), goal setting (behavior/outcome), problem solving, action planning, review behavior goal(s), and review outcome goal(s)*.

The ICBT intervention incorporated BCTs related to education by explaining the rationale for applied relaxation, training through step-by-step guides, and modelling by providing

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instructional videos. These intervention functions could be further addressed in the ICBT intervention through the incorporation of additional content. Some examples may include the provision of podcasts to guide individuals through mindfulness or relaxation practice, and/or printable materials with lists of active and passive strategies so that ICBT users can conveniently access them without having to use the Internet. With regards to BCTs related to persuasion, incentivization, coercion, and enablement, the ICBT intervention focused on developing a better understanding of tinnitus and its effects, developing new habits, identifying negative thoughts and emotions related to tinnitus, and reducing unhelpful feelings and thoughts about tinnitus. These functions were promoted by activities and worksheets that encouraged goal-setting and self-monitoring, as well as the use of a weekly diary to monitor responses to tinnitus. Furthermore, the ICBT intervention created the opportunity to practice and engage with the content and make time for daily active relaxation, as well as time to practice the other intervention strategies through the use of reminders and prompts. These included both external reminders, through guidance and messages, and developing reminders within the environment to aid the application of the strategies to become a habit. The intervention also aimed to encourage individuals to create more time to use the intervention, using cues as practice reminders.

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Instruction on how to perform behavior	Training	Written explanations and step-by-step instructions on how to perform relaxation and breathing techniques											
Behavioral practice rehearsal	Training	Encouraging daily practice and creating opportunity to practice in the real world											
Social support (unspecified)	Enablement	Encouraged to involve significant others in the intervention by sharing the content, what is expected and doing activities together											
Social support (practical)	Enablement	Encouraged to seek additional support from individuals with tinnitus in the form of tinnitus support groups, tinnitus associations											
Goal setting (behavior)	Enablement	Provide opportunity for individuals to set goals to address their tinnitus problems											
Goal setting (outcome)	Enablement	Monitoring of goals during and after undertaking the intervention											
Problem solving	Enablement	Thought analysis, analysis of situations and behaviors that could be contributing to difficulties											
Action planning	Enablement	Pre-planning when new techniques will be practiced, completing worksheets to encourage self-monitoring, habit forming and habit breaking, action planning											
Review behavior goal(s)	Enablement	Completing worksheets to encourage self-monitoring											
Review outcome goal(s).	Enablement	Completing assessment questionnaires to encourage self-monitoring											

Step 8. Mode of Delivery

In this final step, a decision is made concerning the mode(s) of delivery for the intervention (Worksheet 8 in Supplementary materials 9). Modes of delivery include in-person (individual or group) and distance (population- or individual-level). When selecting the preferred mode(s) of delivery, the research team used the APEASE criteria. Most delivery modes were not suitable on the grounds of high costs for development and service provision (i.e., *affordability*). The mode of delivery that was viewed as most suitable was the internet, since this mode would be low cost, allow for the identified BCTs to be effectively delivered (i.e., *practicability*), and would be both acceptable to and reach the intended recipients (i.e., *equity*) of the intervention. This intervention can be modified to be applicable in different contexts as outlined in Beukes et al. (2021).

The key elements identified by applying the BCW were used to create an implementation research logic model as shown in Figure 3.

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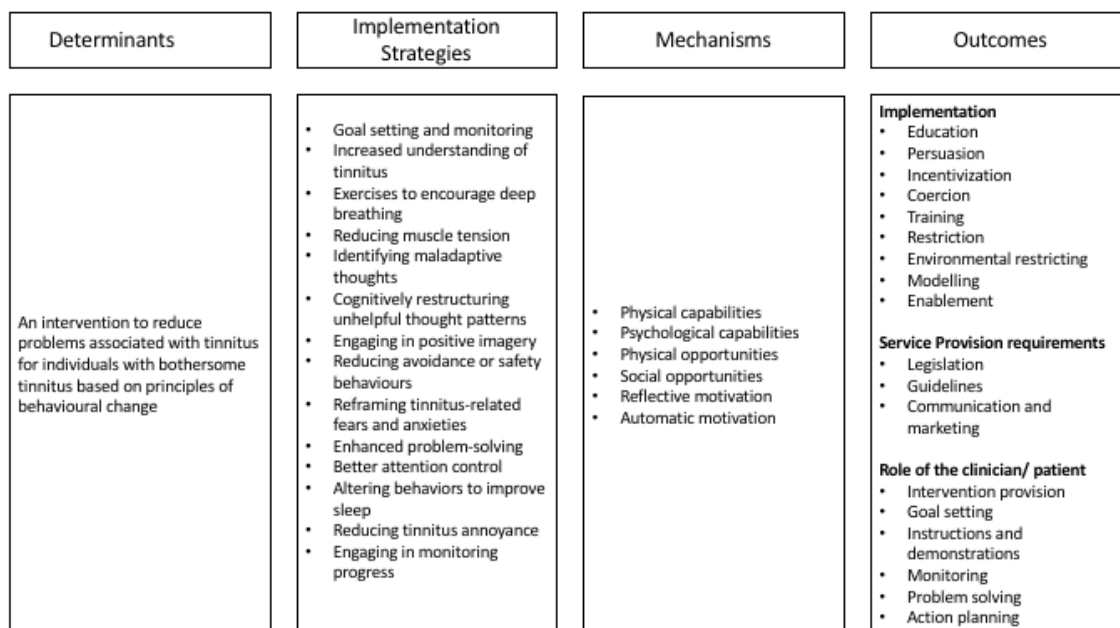


Figure 3: Implementation Research logic Model of the ICBT intervention base on key behavioral change elements that were identified.

Discussion

Tinnitus can result in many adverse effects, such as sleep deprivation, stress, low mood, and anxiety. There are, however, interventions that can reduce tinnitus-related distress, which differ in their approach (e.g., Beukes et al., 2021). ICBT is an effective, evidence-based intervention for tinnitus (Beukes et al., 2019), providing strategies for altered cognitive and behavioral processes to better manage tinnitus with the aim of reducing the associated distress and annoyance. To identify the active ingredients of ICBT intervention for tinnitus, this paper identified the mechanisms of action, underpinned by a contemporary framework of health behavior change, the BCW (Michie et al., 2014).

Using ICBT to improve behavior change

Individuals with bothersome tinnitus may engage in coping strategies to manage the tinnitus experience (Beukes et al., 2018a). However, not all coping strategies are helpful (Andersson et al., 2004); using unhelpful strategies, such as avoidance, may limit an individual's attempt to reduce the awareness and negative effects of tinnitus. ICBT aims to help individuals identify the behaviors that are not helpful and suggests alternative behaviors to improve tinnitus management. The research team mapped out these behaviors and identified the target behaviors chosen to help individuals better manage tinnitus and associated difficulties such as stress and anxiety. The key behaviors included active relaxation, cognitive restructuring, engaging in positive imagery, reducing avoidance behaviors, and the ability to listen to tinnitus. Behaviors such as increased problem solving abilities, attention control, behavioral activation, altering behaviors to improve sleep, and engaging in monitoring progress were helpful for not only tinnitus but other behaviors associated with tinnitus management. For instance, engaging in active relaxation strategies had the potential to impact on managing stress and anxiety. The ease at which the behavior could be measured or monitored varied. Within the ICBT intervention, for example, worksheets were provided in the form of diaries, whereby individuals could rate how well they were able to apply strategies and suggestions (e.g., Beukes et al., 2016; Manchaiah et al., 2020). Thus, self-monitoring was possible, but monitoring them more objectively may have been more difficult. The provision of worksheets and diaries may also not be the only way of measuring and monitoring. Seeking further ways of monitoring these behaviors should be sought.

A key to the ICBT intervention was identifying which the strategies need to be practiced frequently until habituation and/or becomes an unconscious habit. Practicing strategies with others, such as significant others, may improve tinnitus management, but is yet to be

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actively studied in the context of ICBT. In addition, including others should be encouraged, as this may improve engagement with the ICBT, as well as help significant others to better understand tinnitus related difficulties (Hall et al., 2018).

Encouraging engaging with the ICBT Intervention

The COM-B model was applied to identify what needed to change in the person and/or environment to achieve the desired change in behavior. The ICBT intervention focused on using physical and social opportunity to encourage individuals to engage in active relaxation techniques, such as deep breathing and progressive muscle relaxation, as the key physical capabilities required, which have also been included in other tinnitus interventions (Makar, Mukundan, & Gore, 2017).

To help encourage the individual to regularly engage with the intervention and practice the strategies suggested, putting social influences in place was also encouraged. Furthermore, engagement with or learning from other individuals experiencing tinnitus was identified as a facilitator to engagement with ICBT. Modelling through increased social support from friends, family, and others with tinnitus, was used to address social opportunities.

Encouraging these key social opportunities should be modelled in the intervention to promote them due to the positive contribution social connectedness may have (Pryce et al., 2019).

For many individuals, their initial tinnitus experiences may have shaped their beliefs about tinnitus. Some may have been discouraged by the news that there is no cure for tinnitus, hence losing hope that they can manage their condition. Participants completing ICBT have identified that a key factor in successful outcomes is responding differently to their tinnitus (Beukes et al. 2018b, 2018c). The intervention aims to encourage beliefs that responding and

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reacting to the tinnitus differently is possible and that this can result in positive outcomes. Goal setting and monitoring are used as key motivators, together with an action plan to enable goal achievement. To encourage positive beliefs regarding tinnitus habituation, education, persuasion, incentivization, coercion, modelling, and enablement were all incorporated. The strategies suggested are intended to drive helpful behaviors, routines, and habits. Professional guidance within the intervention is used to encouraging participants to create these habits and routines together with completing weekly diaries. Ways of improving engagement with these resources is important to achieving successful outcomes. Automatic motivation (i.e., establishing a routine or habit) were encouraged within ICBT by training, modelling, environmental restructuring, and enablement.

To support the delivery of ICBT, the creation of suitable guidelines was identified. This has been applied by publishing the intervention materials used within this ICBT intervention (see Beukes et al., 2021). Much can be done to enhance the delivery of ICBT in different communities and contexts. Further work should be undertaken to disseminate the intervention more widely.

Implementation Options

For this intervention, the mode of delivery was the Internet, due to the accessibility of this delivery mode. It provided a platform to encourage behavior change included information about the social and environmental consequences, information about health consequences, prompts/cues, self-monitoring of behavior, credible source, demonstration of the behavior, instruction on how to perform the behavior, behavioral practice, rehearsal, and social support. Much of the intervention surrounds education regarding the consequences preventing habituation and strategies to aid habituation. Incentivization, in the form of diaries,

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worksheets and guidance, together with training, persuasion and modeling, by providing step-by-step instructions and demonstration videos, were included as key intervention functions. Enablement was furthermore identified as important for analysis of situations and behaviors that could be contributing to difficulties, preplanning when techniques would be practices, and encouraging self-monitoring.

This intervention can, however, be presented in other formats, including individual sessions, separate mobile smartphone applications, group sessions, and in self-help formats (Beukes et al., 2021). Therefore, further work to expand the applicability and generalizability of ICBT should be undertaken. It is also important to draw inspiration from other similar interventions and smartphone applications (e.g., Aazh and Danesh, 2020; Greenwell et al., 2021; Henry et al., 2020; Mehdi et al., 2020; and how they have incorporated behavioral change elements into their development.

Limitations & Future Research

These results need to be interpreted with the following limitations in mind. Firstly, the barriers and facilitators from a COM-B perspective have not been applied to actual individuals undertaking the ICBT intervention. Secondly, these models do not provide contextual factors that may be influencing individual behavior change. Thirdly, although the intervention materials may provide the required capabilities, opportunities, and motivation to adaptively respond to tinnitus, this may be hampered by the individuals' ability to use the intervention physically and psychologically. As such, future research is now required to identify the actual barriers and enables to using the ICBT by those undertaking the intervention using the COM-B model as an underpinning theoretical framework. Promoting treatment adherence may be a key in improved outcomes. Although the ICBT creates the

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required capabilities, opportunities, and motivation required to manage tinnitus and reduce the annoyance, these may be approached in different ways. Some people may, for instance, prefer text reminders to email reminders or engage with different structures of diary keeping.

In addition, it may be that individuals who do not identify themselves as competent technology users do not take-up the intervention, and ways of encouraging them to effectively do so may be required. This intervention may also not be sufficient for individuals with complex tinnitus presentations such as those with significant hyperacusis or very high levels of anxiety and/ or depression. After identifying possible barriers, the BWC should be applied to select intervention components aimed at overcoming these barriers, as well as enhancing the enablers identified, to further promote the desired behavior change. Although further work is required, identifying the theoretical underpinnings of behavioral change within ICBT may increase the trustworthiness of the intervention, which may, in turn, enhance intervention uptake and engagement.

Summary & Conclusions

Analysis using the BCW has helped to understand the mechanisms of action of an ICBT intervention. The COM-B model was applied to identify what needed to change in the person and/or environment to achieve the desired change in behavior to reduce the impact of tinnitus. The ICBT intervention focused on improving physical capability, such as engaging in progressive muscle relaxation. Further components can be added to improve physical capability, such as provision of podcasts to guide mindfulness and relaxation practice. The ICBT intervention also focused on developing new habits, identifying negative thoughts and emotions related to tinnitus and reducing unhelpful feelings and thoughts about tinnitus as key psychological capabilities. These were promoted by goal-setting and self-monitoring and

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a weekly diary. Improvements indicated should be implemented prior to further ICBT trials.

More needs to be done to enhance the delivery of ICBT in different contexts to make it accessible to more communities.

Acknowledgments

Our thanks are extended to individuals who have helped develop this ICBT intervention, including individuals with tinnitus and tinnitus professionals.

Disclosure of Interest

The authors have no conflicts of interests to declare

Data Availability Statement

All data for this paper is found within the supplementary materials

Funding

This work is partly funded by the National Institute on Deafness and Other Communication Disorders (NIDCD) of the National Institutes of Health (NIH) under the award number R21DC017214 for VM.

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Figure 3: Implementation Research logic Model of the ICBT intervention base on key behavioral change elements that were identified.

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S9: Worksheet identifying of the mode(s) through which the intervention could be delivered.

Supplementary material

Worksheet 1: Defining the tinnitus behavior in behavioral terms.

<i>What is the maladaptive behavior?</i>	Activity avoidance and maladaptive thoughts due to experiencing tinnitus
<i>What is the desired behavior?</i>	Improving successful management by adaptively responding to tinnitus, resulting in habituation reduced tinnitus distress
<i>Where does the behavior occur?</i>	Any context
<i>Who is involved in performing the behavior?</i>	Individual experiencing bothersome tinnitus

Worksheet 2a: Candidate behaviors relevant to the problem behavior identified in step one

Intervention Aim: Adaptively respond to tinnitus to aid habituation
Intervention designer response
<ul style="list-style-type: none"> • Goal setting and monitoring. • Increased understanding of tinnitus to adjust reactions to tinnitus. • Exercises to encourage deep breathing and lower breathing rate. • Reducing muscle tension and arousal by progressive muscle relaxation. • Identify maladaptive thoughts resulting in unhelpful behaviors. • Cognitively restructuring unhelpful thought patterns for behavioral activation. • Engaging in positive imagery to reduce emotional distress and reactions to tinnitus. • Reduce avoidance/safety behaviors. • Reframing tinnitus-related fears and anxiety. • Enhanced problem-solving abilities for relapse prevention. • Better attention control to move attention away from tinnitus. • Altering behaviors to improve sleep. • Ability to listen to tinnitus to reduce tinnitus annoyance. • Engaging in monitoring progress through weekly diary keeping.

Worksheet 2b: Criteria for prioritizing the identified candidate behaviors

Potential target behaviors relevant to improving management of tinnitus	Impact of behavior change^a	Likelihood of changing behaviors^a	Spill-over score^a (i.e., impact on other behaviors, such as stress or anxiety)	Measurement score^a (i.e., monitoring)
Goal setting and monitoring	Promising	Promising	Promising	Promising
Increased understanding of tinnitus to adjust reactions to tinnitus	Promising	Promising	Very promising	Unpromising but worth considering
Exercises to encourage deep breathing and lower breathing rate	Promising	Promising	Very promising	Promising
Reducing muscle tension and arousal by progressive muscle relaxation	Promising	Promising	Very promising	Promising
Identify maladaptive thoughts resulting in unhelpful behaviors	Promising	Promising	Very promising	Promising
Restructuring unhelpful thought patterns for behavioral activation		Promising	Very promising	Promising
Engaging in positive imagery to reduce emotional distress and reactions to tinnitus	Promising	Promising	Very promising	Promising
Reduce avoidance/safety behaviors	Promising	Promising	Very promising	Unpromising but worth considering
Less hindered by fears or anxiety regarding tinnitus	Promising	Promising	Very promising	Unpromising but worth considering
Increase problem solving abilities for relapse prevention	Promising	Promising	Very promising	Unpromising but worth considering
Attention control to move attention away from tinnitus	Promising	Promising	Promising	Unpromising but worth considering
Altering behaviors to improve sleep	Promising	Promising	Promising	Promising
Ability to listen to tinnitus to reduce tinnitus annoyance	Promising	Promising	Promising	Unpromising but worth considering
Writing a weekly diary	Promising	Promising	Promising	Promising

^a Rate as: unacceptable, unpromising but worth considering, promising, very promising

Worksheet 3: Describe the target behavior according to who needs to do what, when, where, how often and with whom.

Target behavior	Adaptive response to tinnitus
<i>Who</i> needs to perform the behavior?	Individual experiencing tinnitus by applying the intervention materials.
<i>What</i> do they need to do differently to achieve desired change?	React adaptively to tinnitus by implementing the strategies suggested by the intervention.
<i>When</i> do they need to do it?	Regularly, initially by daily practice of the strategies, and then anytime as needed until habituation is achieved or the strategy becomes an unconscious habit.
<i>Where</i> do they need to do it?	Any context, which may be alone initially and in time also when between other people and in varying contexts.
<i>How often</i> do they need to do it?	Ideally daily initially and then as frequently as necessary until habituation is achieved or the strategy becomes an unconscious habit.
<i>With whom</i> do they need to do it?	Alone or together with significant others.

Worksheet 4: Behavioral analysis of what needs to change for the target behavior to occur.

COM-B components	Theoretical domains linking to COM-B component	What needs to happen for target behavior to occur?
Physical capability	Physical skills <i>Do you know how to adaptively respond to tinnitus?</i>	<ul style="list-style-type: none"> • Have better physical skills to adaptively respond to tinnitus such as engaging in deep breathing to lower breathing rate and progressive muscle relaxation.
Psychological capability	Knowledge <i>Do you know about adaptive responses to tinnitus?</i>	<ul style="list-style-type: none"> • Have a better understanding of tinnitus, the effects of tinnitus and ways to adaptively responding to it.
	Memory, decision, and attention processes <i>Is adaptively responding to tinnitus something you usually do?</i>	<ul style="list-style-type: none"> • Develop new habits to adaptively respond to tinnitus in a more positive way. • Identifying negative thoughts and emotions related to tinnitus. • Reduce unhelpful feelings or thoughts about tinnitus.
	Behavioral regulation <i>Do you have systems in place for monitoring whether you are adaptively responding to tinnitus?</i>	<ul style="list-style-type: none"> • Develop skills of goal-setting and self-monitoring. • Use a weekly diary to monitor responses to tinnitus.
Physical opportunity	Environmental context and resources <i>To what extent do physical or resource factors facilitate/hinder an adaptive respond to tinnitus?</i>	<ul style="list-style-type: none"> • Create more time during the day to engage with the intervention content. • Create daily sessions for active relaxation and practicing the suggested intervention strategies. • Applying the strategies suggested when tinnitus is problematic. • Have reminders/prompts to practice strategies until they become a habit.
Social opportunity	Social influences <i>To what extent do social influences facilitate/hinder an adaptive response to tinnitus?</i>	<ul style="list-style-type: none"> • Support from friends/family to regularly engage with the intervention and practice the strategies.

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		<ul style="list-style-type: none"> Engage with or learning from other individuals experiencing tinnitus for additional support.
<p>Reflective motivation</p>	<p>Beliefs about capabilities <i>How difficult is it for you to adaptively respond to tinnitus?</i></p> <p>Optimism <i>How confident are you that adaptively responding to tinnitus will improve quality of life?</i></p> <p>Belief about consequences <i>What do you think will happen if you adaptively respond to tinnitus?</i></p> <p>Goals <i>How much do you want to adaptively respond to tinnitus?</i></p>	<ul style="list-style-type: none"> Hold beliefs that adaptively responding to tinnitus is possible. Believing that adaptively responding to tinnitus is important to reduce negative consequences. Believing that adaptively responding to tinnitus will result in positive outcomes. Mental representations of outcomes or end states that the individual wants to achieve. Goal setting and monitoring to add motivation.
<p>Automatic motivation</p>	<p>Reinforcement <i>Are their incentives to regularly adaptively respond to tinnitus?</i></p>	<ul style="list-style-type: none"> Develop an established routines and habits for adaptively responding to tinnitus to alleviate negative consequences. Completing weekly diaries. Engaging with professional guidance during the intervention delivery.
<p>Behavioral diagnosis of the relevant COM-B components</p>	<p>Physical/psychological capability, physical/social opportunity, and reflective/automatic motivation need to change for the target behavior to occur.</p>	

Worksheet 5: Consideration of the candidate intervention functions using the APEASE criteria.

Candidate intervention function	Definition	COM-B component	Meet the APEASE criteria?
Education	Increasing knowledge or understanding (e.g., <i>providing information to promote an adaptive response to tinnitus</i>)	<p>Psychological capability</p> <ul style="list-style-type: none"> Educate about ways of enacting the desired behavior/ avoiding undesired behaviors via educational modules and videos. <p>Reflective motivation</p> <ul style="list-style-type: none"> Educate to create more positive beliefs about the desired behavior. 	Yes
Persuasion	Using communication to induce positive or negative feelings or stimulate action (e.g., <i>using imagery to motivate adaptive responses to tinnitus</i>)	<p>Reflective motivation</p> <ul style="list-style-type: none"> Persuade to create more positive beliefs about the desired behavior. Persuade to feel more positively about the desired behavior. 	Yes
Incentivization	Creating an expectation of reward (e.g., <i>highlight the benefits of engaging in an adaptive response to tinnitus</i>)	<p>Reflective motivation</p> <ul style="list-style-type: none"> Incentivize to feel more positively about the desired behavior. Goal setting with the view of improving quality of life and engaging and participating in activities. 	Yes
Coercion	Creating an expectation of punishment or cost (e.g., <i>highlighting how no action will not improve tinnitus</i>)	<p>Reflective motivation</p> <ul style="list-style-type: none"> Coerce to feel more positively about the desired behavior. 	Yes
Training	Imparting skills (e.g., <i>training to facilitate an adaptive response to tinnitus</i>)	<p>Physical capability</p> <ul style="list-style-type: none"> Train physical skills required for the desired behavior through step-by-step instructions and demonstration videos. <p>Psychological capability</p> <ul style="list-style-type: none"> Train cognitive skills required for the desired behavior. Train development of mental strength required for desired behavior. Train sustained resistance to undesired behavior(s). <p>Physical opportunity</p> <ul style="list-style-type: none"> Train to reduce competing time demands. 	Yes

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		<ul style="list-style-type: none"> • Train to provide cues/ prompts for desired behavior. <p>Automatic motivation</p> <ul style="list-style-type: none"> • Train to strengthen habitual engagement in the desired behavior. 	
Restriction	Using rules to increase the opportunity to engage in the target behavior/ reduce opportunity to engage in competing behaviors (e.g., <i>Prohibiting a non-adaptive response to tinnitus</i>)	<p>Physical/ Social opportunity</p> <ul style="list-style-type: none"> • Restriction to reduce undesired behavior(s) surrounding habits that have a negative impact (e.g., for sleep). 	Yes
Environmental restructuring	Changing the physical or social context (e.g., <i>providing reminders to encourage an adaptive response to tinnitus</i>)	<p>Physical opportunity</p> <ul style="list-style-type: none"> • Restructure the environment to reduce competing time demands. • Restructure the environment to provide cues and prompts for desired behavior. • Restructure the environment to reduce difficulties regarding concentration, sleep and hearing difficulties. <p>Social opportunity</p> <ul style="list-style-type: none"> • Restructure the environment to increase social support. 	Yes
Modelling	Providing an example for people to aspire to or imitate (e.g., <i>expert videos, using patient testimonials/ dramatizations of how they have adaptively responded to tinnitus</i>)	<p>Social opportunity</p> <ul style="list-style-type: none"> • Modelling to shape people’s ways of thinking. <p>Reflective motivation</p> <ul style="list-style-type: none"> • Model to feel more positively about the desired behavior. <p>Automatic motivation</p> <ul style="list-style-type: none"> • model desired behavior to induce automatic imitation. 	Yes
Enablement	Increasing means/ reducing barriers to increase capability or opportunity (e.g., <i>behavioral support to adaptively respond to tinnitus</i>)	<p>Psychological capability</p> <ul style="list-style-type: none"> • Enable development of mental strength required for desired behavior through the strategies provided. • Enable sustained resistance to undesired behavior(s) through the strategies provided. <p>Reflective motivation</p>	Yes

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		<ul style="list-style-type: none">• Enable to feel more positively about the desired behavior. <p><i>Automatic motivation</i></p> <ul style="list-style-type: none">• Enable to strengthen habitual engagement in desired behavior.	
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Worksheet 6: Policy categories that might support the identified intervention functions.

Intervention function	COM-B component	Potential policy categories	Does the policy meet the APEASE criteria in the context of facilitating an adaptive response to tinnitus?
Education	Psychological capability Reflective motivation	Communication/marketing	Not applicable in this context
		Guidelines	Possible in the long-term but not present
		Regulation	Not relevant in this context
		Legislation	Not relevant in this context
		Service provision	Possible in the long-term but not presently
Persuasion	Reflective motivation	Communication/marketing	Not applicable in this context
		Guidelines	Possible in the long-term but not present
		Regulation	Not relevant in this context
		Legislation	Not relevant in this context
		Service provision	Possible in the long-term but not presently
Incentivization	Reflective motivation	Communication/marketing	Not applicable in this context
		Guidelines	Not practicable in this context
		Fiscal measures	Not relevant in this context
		Regulation	Not relevant in this context
		Legislation	Not relevant in this context
		Service provision	Possible in the long-term but not presently
Coercion	Reflective motivation	Communication/marketing	Not practicable in this context
		Guidelines	Possible in the long-term but not present
		Fiscal measures	Not relevant in this context
		Regulation	Not relevant in this context
		Legislation	Not relevant in this context
		Service provision	Possible in the long-term but not presently
Training	Physical capability Psychological capability Physical opportunity Automatic motivation	Guidelines	Possible in the long-term but not present
		Fiscal measures	Not relevant in this context
		Regulation	Not relevant in this context
		Legislation	Not relevant in this context
		Service provision	Possible in the long-term but not present
Modelling	Social opportunity Reflective motivation Automatic motivation	Communication/marketing	Not applicable in this context
		Service provision	Possible in the long-term but not presently
Enablement	Psychological capability	Guidelines	Not relevant in this context
		Fiscal measures	Not relevant in this context

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	Reflective motivation	Regulation	Not relevant in this context
	Automatic motivation	Legislation	Not relevant in this context
		Environment/ social planning	Not practical in this context
		Service provision	Possible in the long-term but not presently
Policy categories selected: Guidelines and service provision			

Worksheet 7: Behavior Change Techniques BCTs identified based in intervention functions selected in Step 5.

Intervention function	COM-B component	Most frequently used BCTs	Does the policy meet the APEASE criteria?
Education	Psychological capability Reflective motivation	Information about social and environmental consequences	Yes, encouraging social support and environmental adaptations
		Information about health consequences	Yes, outlining the effects of anxiety and relaxation
		Feedback on behavior	Yes, delivered by weekly guidance
		Feedback on outcome(s) of the behavior	Yes, delivered by weekly guidance
		Prompts/cues	Yes, through reminder messages and encouragement to use own prompts
		Self-monitoring of behavior	Yes, encouraged by weekly diary completion
Persuasion	Reflective motivation	Credible source	Yes, outlining evidence behind the strategies used
		Information about social and environmental consequences	Yes, encouraging social support and environmental adaptations
		Information about health consequences	Yes, outlining the effects of anxiety and relaxation
		Feedback on behavior	Yes, delivered by weekly guidance
		Feedback on outcome(s) of the behavior	Yes, delivered by weekly guidance
Incentivization	Reflective motivation	Feedback on behavior	Yes, delivered by weekly guidance
		Feedback on outcome(s) of the behavior	Yes, delivered by weekly guidance
		Monitoring of behavior by others without evidence of feedback	Unlikely to be effective in this context
		Monitoring outcome of behavior by others without evidence of feedback	Unlikely to be effective in this context
		Self-monitoring of behavior	Yes, encouraged by weekly diary completion
Coercion	Reflective motivation	Feedback on behavior	As above
		Feedback on outcome(s) of the behavior	As above
		Monitoring of behavior by others without evidence of feedback	As above

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		Monitoring outcome of behavior by others without evidence of feedback	As above
		Self-monitoring of behavior	As above
Training	Physical capability Psychological capability Physical opportunity Automatic motivation	Demonstration of the behavior	Yes
		Instruction on how to perform behavior	Yes
		Feedback on behavior	Yes, delivered by weekly guidance
		Feedback on outcome(s) of the behavior	Yes, delivered by weekly guidance
		Self-monitoring of behavior	Yes, encouraged by weekly diary completion
		Behavioral practice rehearsal	Yes, encouraged by weekly diary completion
Modelling	Social opportunity Reflective motivation Automatic motivation	Demonstration of the behavior	Yes, including the use of written guides and videos
Enablement	Psychological capability Reflective motivation Automatic motivation	Social support (unspecified)	Yes, encouraging social support
		Social support (practical)	Yes, encouraging social support by engaging with other individuals experiencing tinnitus
		Goal setting (behavior)	Yes, prior to starting the intervention
		Goal setting (outcome)	Yes, monitored during and after completion
		Adding objects to the environment	Not practical to deliver
		Problem solving	Yes, including relapse prevention
		Action planning	Yes, including relapse prevention
		Self-monitoring of behavior	Yes, encouraged by weekly diary completion
		Restructuring the physical environment	Yes, encouraged to reduce difficulties with sleep, focus, and hearing
		Review behavior goal(s)	Yes, weekly and after completion of the intervention
		Review outcome goal(s)	Yes, monitored during and after the intervention
<p>Most frequently used BCTs selected: Information about social and environmental consequences Information about health consequences Prompts/cues</p>			

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Self-monitoring of behavior
Credible source
Demonstration of the behavior
Instruction on how to perform behavior
behavioral practice rehearsal
Social support (unspecified)
Social support (practical)
Goal setting (behavior)
Goal setting (outcome)
Problem solving
Action planning
Review behavior goals
Review outcome goals

Worksheet 8: identification of the mode(s) through which the intervention could be delivered.

Mode of delivery				Does the policy meet the APEASE criteria in the context of facilitating an adaptive response to tinnitus?
In-person	Individual			Possible
	Group			Possible
Distance	Population-level	Broadcast media	TV	No
			Radio	No
			Billboard	No
			Poster	No
			Newspaper	No
			Leaflet	No
			Internet or web app function	Yes, the present intervention discussed
	Mobile app	Possible but expensive		
	Individual-level	Phone	Phone helpline	No
			Mobile phone text	No
Individually accessed computer program		Possible		