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Listen carefully: Volume adjustment behavior for portable music player usage with headphones

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Abstract

The risk of hearing damage caused by self-exposure to high sound pressure levels has increased due to the availability of portable music players (PMP) allowing users to listen to music through headphones in various everyday situations. Previous research primarily focuses on the extent and effect of high-level sound exposure, but rarely on what causes people to actively choose potentially damaging listening levels of music. The present aim is to investigate people's behavior in relation to volume control of PMP's. We take a structural qualitative approach for explorative data collection followed by an in depth discussion within the sample group. The target group for this study are young people aged 16-30, which is considered a high-risk group in the literature. Based on a clarification of the triggers crucial to the users' volume adjustments, we aim to develop a framework for designing solutions to reduce inexpedient PMP listening behavior without compromising the user experience.

Keywords: MIHL, NIHL, Music Listening, KJ-technique

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Introduction

According to a report by the Scientific Committee on Emerging and Newly Identified Health Risks [13], music-induced hearing loss (MIHL) has become a severe problem among young people using portable music players (PMP's) with headphones. About 5% to 10% of young people using PMP's are at risk of developing MIHL after five or more years of exposure, due to the combination of chosen sound intensity levels and exposure duration.

Despite the significant risk of MIHL, not much research has previously focused on why young people tend to expose themselves to music with an hazardous high sound intensity [13, 20]. Some studies argue that it would be efficient to provide specific information or education regarding the danger of high sound intensities [19], while others suggest that to reduce the risk of MIHL, strategies to limit maximum sound levels and exposure durations from PMP's are necessary [5]. However, these solutions may not be adequate, as young people seem to be prone to disable control mechanisms in order to adjust volume setting themselves [19], and the use information for altering young people's music listening behavior also seems to fall short of it's intention [21]. This indicates that a detailed overview of the underlying motivations supporting hazardous habits are vital in order to modify the listening behavior. Hence, we explore motivations behind young people's choice of volume setting. From this, our aim is to provide a structured overview of young people's music listening behavior when using PMP's with headphones.

Risky listening behaviors are highly linked to the fact that young people tend to act upon intrinsic rewards [21]. The theory of Consideration of Future Consequences (CFC) explains how some individuals do not consider distant, probabilistic outcomes of their action, as they are influenced by immediate, concrete outcomes [16]. Additionally, the Protection Motivation Theory (PMT) describes how maladaptive response rewards decrease the probability that an individual changes behavior [6], as benefits of listening to loud music become motivation for keeping a hazardous listening behavior. Furthermore, the listener may not consider any behavior change if listening to loud music is a habit [21]. Habits do not require any conscious decision making, but a trigger associated with a specific motivation is required to initiate an action [17]. For instance, when a listener's goal is to improve performance of a physical activity, the listener may want to block out distractions by listening to music. The presence of a distraction will automatically trigger the action of increasing the sound intensity to achieve the goal. From these three theories, we argue that whether the behavior is premeditated or not, triggers of volume adjustments and benefits of music listening are important, when understanding young peoples listening behavior.

In the following, we present the methodology used for investigating this topic. Furthermore, the main findings of the study are summarized in a model of young people's listening behavior considering the triggers and benefits that influence the choice of listening level. Finally, the results are discussed in view of elements for further investigation.

Method

To explore young people's music listening behavior using PMP's with headphones, a workshop was conducted with the purpose of deriving triggers and benefits related to volume adjustments. Here, a qualitative approach provided in-depth information about why benefits motivate listeners to select risky exposure level, and which triggers provoke a volume adjustment.

2.1 Workshop design

To define triggers, a KJ-technique was implemented, containing three phases: 1) brainstorming about experienced triggers; 2) clustering triggers; and 3) diagramming clusters (A-type and B-type diagramming). A fourth phase was implemented to the workshop containing a focus group interview to discuss the outcome of the previous phases to achieve a deeper understanding of music listening behavior.

The KJ-technique is an affinity diagramming method invented by Kawakita Jiro in 1953 with the purpose of creating orderly systems and relationships from a vast amount of brainstorm data [14]. For the brainstorming and clustering phases, we adapted guidelines from the KJ-technique approach by [15]. This approach generates a short and productive workshop, avoiding communication between the participants during the brainstorm and clustering phases. The research question presented to the participants and used as a base for the entire workshop was:

"*What makes you adjust the sound intensity level on your portable music player?*" (translated from Danish)

In an attempt to make the participants examine the topic more widely, a series of unrelated pictures representing objects or animals (e.g. panda, dice, and abstract art) was presented. This additional stimulation should provoke horizontal thinking without biasing the participants to think about specific PMP related situations [3]. In the diagramming phase, relationships and structures of the triggers become visualized. For A-type diagramming, we offered two diagramming techniques: spatial diagramming and relationship lines. The aim of the former is to arrange clusters spatially according to their similarity or difference, and the aim of the later is to try to explain the relationship between clusters by adding connecting lines with descriptions of the relationships. For the subsequent B-type diagramming, the participants had to verbally describe their diagram, pointing out how the diagramming tools were used. This gave the facilitator an opportunity to ask questions to unspecified areas.

2.2 Estimate of sound exposure

Average daily exposure levels (L_{EX}) were estimated using each participant's PMP connected to the same set of headphones, mounted on a head and torso simulator (HATS) fitted with an ear [8] and a pinna [10, type 3.3] simulator. The signal from the HATS was converted to the diffuse-field related equivalent continuous A-weighted sound pressure level ($L_{DF,Aeq,1s}$) averaged over 1 second, using the procedure outlined in [9], and displayed on a calibrated dB scale on the from of the HATS. The PMPs (mostly smart phones) were set to played back music using the last sound settings used by the participants before arriving at the workshop. Measurements were made every 10 seconds for a period of 10 minutes, giving a total of 60 values for each PMP. The L_{EX} for each participant was then calculated using the median $L_{DF,Aeq,1s}$ and self reported average daily exposure time. The resulting exposure levels were used to assess whether the sample represents young people with hazardous listening habits ($L_{EX} > 80$ dB).

2.3 Participants

Four workshops were conducted with groups consisting of four to six members (see table 1). In total 21 volunteers participated, recruited in the city of Aalborg (Denmark) using opportunity sampling among university and high school students. Aiming for a high level of cohesiveness within each group, we chose demographically homogeneous groups, with strong acquaintanceship and the same educational background as suggested in [12]. The participants varied in age between the workshop groups, covering the age range between 15 and 26. From the estimated L_{EX}, we found that three participants had a hazardous listening behavior.

Group	Gender	Age	Education	L_{EX} dB
1	2F, 4M	20-24	Bachelor	67.6, 63.8, 54.3, 71.01, **87.3**, *58.2*
2	5M	23-26	Master	**90.0**, 75.3, 68.8, 65.4, *56.0*
3	4F, 2M	19-23	Bachelor	72.0, 70.6, 66.1, **81.6**, *57.5*, *59.0*
4	4F	15-16	High School	67.6, 59.5, *62.5*, *57.7*

Table 1: Structure of the four focus groups and measured exposure levels. Three participants had an estimated $L_{EX} > 80$ dB shown in **bold**. Exposure levels shown in *italics* were calculated using the minimum output of the measurement system $L_{DF,Aeq,1s} = 65$ dB as the measured levels were lower.

2.4 Procedure

The workshops was held in Danish and took place at Aalborg University, Denmark, with few days in between. One facilitator and one assistant guided the group of participants through the workshop. The procedure and guidelines were introduced to the participants on a slide show before each phase. The workshop lasted approximately 2 hours, where 45 minutes were reserved for the focus group interview.

The workshop began with a warm up of five minutes, where the participants discussed the differences between listening to music though loudspeakers and headphones.

Initiating the KJ-technique, the participants wrote answers to the research question individually, without communicating, on post-it's. All answers that came to mind were relevant, however, each post-it's should contain only one answer. We aimed for a duration of approximately 10 minutes for the brainstorm and half way through, the series of unrelated pictures was presented on the slide show.

Next, the participants spread out their post-it's randomly on a wall and read each others post-it's and arranged similar post-it's into clusters without communicating. Remaining silent, the participants wrote headlines for each cluster on new post-it's. If a participant did not agree with the suggested headline, an alternative was added by this participant.

Finalizing the KJ-technique, the participants arranged and connected the clusters using A-type diagramming followed by the B-type diagramming presented by one participant.

From here, the participants sat down and discussed the outcome of the KJ-technique in a focus group interview held by the facilitator and the assistant. The workshop ended after having the participants fill out a questionnaire covering their listening habits and demography.

Analysis

We analyzed data from the workshop using data coding systems with inspiration from Grounded Theory, but with a more deductive approach due to the workshop structure. We used three strategies: Focused Coding; Axial Coding; and Theoretical Coding [4].

For Focused Coding, we grouped the data from the clustering phase into 13 trigger categories providing an overview of the different trigger areas. Afterwards, we split a transcribed version of the interviews into 238 segments and compared them with the trigger categories.

Through the Axial Coding, we found three dimensions of triggers: *Trigger Condition*, the element in a situation that makes the trigger occur; *Volume Adjustment*, the action the listener performs due to the trigger; and *Benefits*, the expected outcome of adjusting the volume setting with a specific goal in mind. From these three dimensions, we were able to define 38 triggers which were sorted into the following categories: *Aural Attention, Battery Life, Enhance Activity, Genre, Inner State, MIHL, Music Preferences, Playback Compromising the Music Experience, Singing Along, and Social Context*.

Using Theoretical Coding we conceptualized the results from Axial Coding by analyzing relationships between triggers and benefits. We derived 30 different benefits, which were sorted into the following nine categories: *Affect Mood, Behavior in Public Contexts, Derive the Desired Audio, Drown Out Unwanted Audio, Experience the Music, Performance Booster, Regulate Energy, Regulate Focus of Attention, and Unclassified Benefits*. Benefits were found useful in conceptualizing music listening behavior, while triggers described the elements in everyday situations that materialize the desire of benefits into a volume adjustment.

Model Describing Music Listening Behavior

Results from the workshop were compiled into a model, describing the processes of determining the *Preferred Listening Level* for young people.

Data indicates that the participants were motivated to choose a specific listening level by evaluating the benefits that are crucial for achieving the goal, which we compiled into a number of factors (see figure 1). Within each factor, one group of benefits leads to a high sound intensity while the other leads to a low sound intensity, creating bipolar spans for each factor. If all spans overlap, the *Preferred Listening Level* will be ideal, as the listener can achieve all the desired benefits. However, if not all factor spans overlap, the listener makes compromises and chooses a listening level based on the factors crucial to the current situation. In the following, we present the factors that influence young people's music listening behavior.

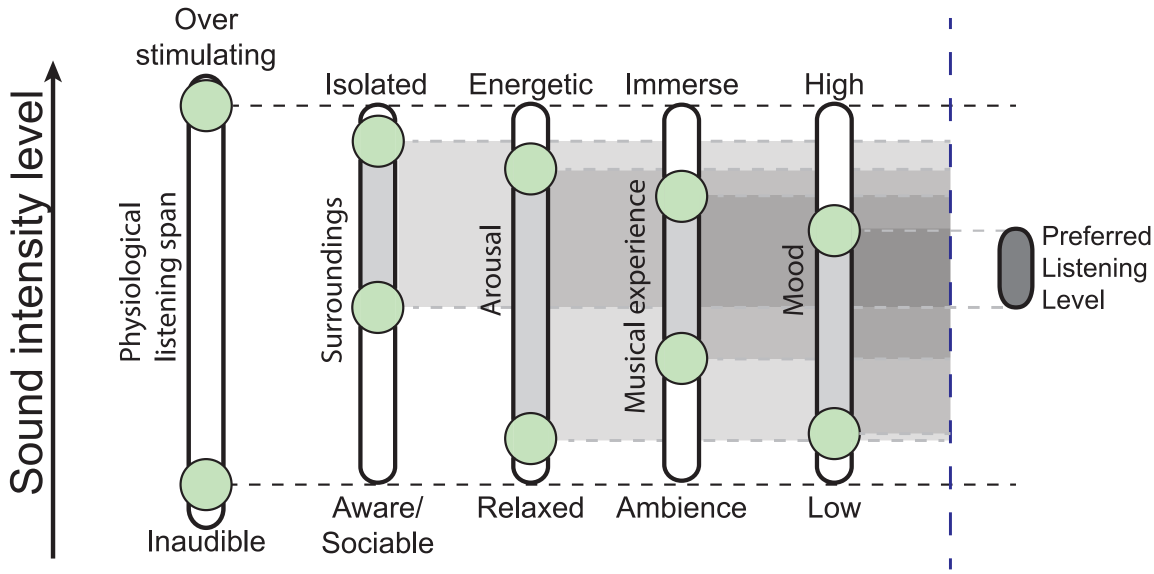

Figure 1: Model illustrating the conditions for the Preferred Listening Level. Each factor that affects the *Preferred Listening Level* is illustrated as a vertical slide bar on the model, where the upper and lower limits represent different benefits that can be achieved by a specific volume setting.

The *Physiological Listening Span* is the most crucial span as it serves as a point of reference. This span ranges from the music being at a level just above *Inaudible* to a level just below *Over stimulating*. The lower limit can be influenced by noise in the surroundings, to which some participants explained that the music must overpower masking from ambient noise. The upper limit can be influenced by long periods of listening; poor playback quality; unexpected sound intensity changes, or in general levels that result in unpleasantness. The *Physiological Listening Span* sets the overall limit for the listener's volume setting, no matter which triggers that may occur. For the listener to achieve any goal with the music, it must be loud enough to be audible, yet, not too loud to be unpleasant.

Participants stated that they desire varying levels of environment sound for different situations. The factor *Surroundings* ranges from *Aware/Sociable* to *Isolation*. If the span lies near *Aware/-Sociable*, the sound intensity level allows the listener to hear the surroundings. This way, the participants explained that they were able to get relevant information (e.g. in public areas or when commuting in traffic) while listening to music. Moreover, they stressed the importance of complying to social norms, such as showing consideration for other people. Conversely, if the span lies near *Isolation*, the sound intensity level drowns out the surroundings. Here, the participants explained that they desire aural isolation from the surroundings by masking unwanted stimuli.

Many participants explained that their desired *Arousal* is related to the sound intensity. One workshop group argued for a correlation between arousal and loudness stating that a listening level placed in the upper end of the slide bar corresponds to high arousal and vice versa. The span lies near *Relaxed*, when the listener wants to unwind or go to sleep, while the span lies near *Energetic*, when the listener wants to boost the energy level (e.g. performing physical activities, waking up, or preparing for festive social events).

The listener might consider how much *Musical Experience* the activity affords. Here, we define a span between *Ambience* and *Immerse*. When the span lies near *Immerse*, the sound intensity allows the listener to immerse into the music and can thereby get inspiration from lyrics; listen for details; or to adjust the state of mind. Here, listening to music become the primary activity. Contrary, when the span lies near *Ambience*, the sound intensity allows the music to supplement the primary activity, serving as a pleasant ambient sound.

Mood affects the *Preferred Listening Level* as well, since different emotional states afford different sound intensities. This span ranges from *High* to *Low*. Moods like happy or upset afford a higher sound intensity level, and are therefore defined as High Moods, while moods that afford a low sound intensity level like sad and relaxed are defined as Low Moods. This means, that when the span lies near *High*, the high sound intensity is used to keep or gain the desired High Mood providing an uplifting effect. If the span lies near *Low*, the sound intensity level is used to keep or achieve a *Low mood*, when a soothing effect is desired.

Discussion

Our analysis of qualitative data resulted in a model of young people's music listening behavior, outlining the psychological causes as well as an overview of the factors crucial to a sound intensity. Several benefits described in the model relating to high sound intensity correlate with previous research, stating that when listening to loud music, the listener can increase energy [18], immerse into the music [7], and get emotionally affected [2]. Through this investigation, we attempt to understand, the types and degree of benefits related to volume settings and connect these to the suggested triggers. Additionally, our model outlines a novel theoretical framework of benefits related to music listening behavior, and as the present data suggests, these benefits are bipolar. Benefits should not be seen as achieved or not achieved, instead, the listener can desire a degree of a benefit (e.g. a degree of isolation from surroundings).

This theoretical framework suggests that based on the most important goal of music listening when using a PMP with headphones, listeners arguably need to make compromises, when finding the best possible sound intensity. Based on this, the preferred listening level should not be seen as one single sound intensity, as this would require continuous volume adjustments each time a factor span changes slightly. Rather, the span for each factor should be seen as an interval of acceptable deviation.

Even though this study provides a new way of thinking about young people's listening behaviors, there are still some elements that need to be addressed. First, our data suggests that the genre of the track is related to young people's listening behavior and the preferred listening level, but not as an independent factor. Instead, the music genre alters other factors, and thereby changes how the listener reaches the desired goals of music listening. For instance, the right genre can make it easier for young people to achieve the desired degree of arousal, music experience, or uplifted mood.

The absence of MIHL in the model is a result of this factor not being generalizable for the group in the present study. A few workshop participants thought of this topic themselves, but it was clear that the majority was not particularly affected in their behavior by the risk of hearing loss. The data was produced on the basis of the participants' brainstorm from the KJ-technique, bias from the research team was avoided as much as possible by not asking about anything in the focus group interview that the participants did not mention themselves. Reinforcing the validity of this finding.

As this study had an exploratory approach, some parts of the model would benefit from a deeper investigation to understand young peoples listening behavior. For instance, to understand the difference between hazardous and safe listening behaviors, the weight of the factors along with the placement and size of the spans for each factor should be investigated for various situations and activities using PMP with headphones. With this additional knowledge, design solutions preventing MIHL will have an expanded basis that can take user experience into account.

To prevent hazardous listening behaviors, we suggest focusing on removing triggers related to upward volume adjustments and make listeners aware of immediate benefits related to low sound intensity levels. As an example, removing triggers occurring due to noise from the surroundings could be achieved to some extend by the use of headphones providing high sound insulation. If these triggers are reduced or removed, no habitual action related to noise in surroundings will be performed. This could also have adverse effects, limiting the degree of surrounding awareness (*Aware/Social* from Surroundings factor) attainable for the particular set of headphones. Another suggestion is to limit changes in level due changes in program material by adjusting playback level to a constant program loudness, as suggested in [11]. This will hopefully prevent people from adjusting the volume setting due to sudden changes in sound intensity level in the playback.

Level control solutions for PMP could provide a graphical presentations of immediate benefits related to soft music (e.g. being *Aware* or *Relaxed*). The aim would be to make people deliberate upon their decision and choose the preferred listening level on the basis of the benefits they find relevant. This design solution should not inflict complications for the main part of the listeners, who do not have hazardous listening behaviors. We believe that a solution based on this concept will avoid negative influence on the user experience, as this solution does is not based on limitations or reprimands. People tend to consider less elements than they actually care about when making a decision [1], thus, reminding them of other benefits can alter the importance of the benefits associated with loud and soft music. We believe that this information would be seen as useful and welcome. The idea is that design solutions have the ability to initiate or maintain protective habits, not punish risky behavior.

Possible level control schemes could be developed based on the listener indication the current desired goal or activity while choosing music, this could provide information to ensure that benefits related to the specific goal or situation can be presented to the listener, while keeping the sound intensity level within the models preferred listening level. 6

Conclusion

This study of young people's music listening behavior using headphones investigated what triggers a group of 21 young people to adjust the volume on their portable music player and what benefits they expect from this adjustment.

We have found that specific elements of the surroundings, degree of arousal, musical experience, and mood affect the preferred listening level. These factors are intrinsically connected in the processes of selecting a preferred listening level in various situations of music listening. Findings suggest that listeners use the benefits of higher and lower sound intensities to approach an ideal sound level.

The present results contribute to the understanding of the decision making process of young people's behavior when using portable music players with headphones and present a theoretical framework for developing level control strategies that take into account the user experience of the listener.

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