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ABSTRACT:
Music is generally considered a pleasant and positive stimulus. However, constant exposure to loud music, especially in acoustic environments where individuals have limited control, can transform music listening into a potentially distressing and detrimental experience. In certain contexts, music can therefore be classified as noise, with implications for mental well-being and cognitive functioning. In our paper, we delve into the complexities of this paradoxical phenomenon, discussing the implications of commonly experienced situations in which music becomes a source of discomfort due to its intensity or forced exposure. Our exploration of the effects of music exposure focuses on individual differences, encompassing clinical sensitivity (hyperacusis, misophonia), non-clinical sensitivity (noise sensitivity, sensory-processing sensitivity), and music-related individual factors (sensitivity to music pleasure). We argue that only by recognizing these aspects, significant progress can be made in prevention strategies and interventions. Our aim is to identify regulatory gaps and propose strategies to mitigate potential music-related discomfort in order to promote the creation of auditory environments that align with individual preferences and sensitivities. This approach is particularly relevant when considering clinical and non-clinical populations, for whom sensory sensitivities may substantially influence the quality of life. © 2024 Acoustical Society of America.

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I. INTRODUCTION
With advancements in music delivery technology and its widespread accessibility, we have more opportunities than ever to listen to music that we enjoy and to develop strategies for using it to achieve various goals (North et al., 2004). The primary reasons for music exposure typically include emotion regulation, background listening coupled with other activities, and enjoying the music itself (Chamorro-Premuzic et al., 2012; Chamorro-Premuzic and Furnham, 2007; North et al., 2004). Listening to preferred music is shown to assist in learning (Gold et al., 2013), mitigate anxiety (Bradt et al., 2013), and reduce pain (for a review, see Nilsson, 2008). However, positive outcomes of music listening are tightly related to the personal choice over how, when, and to what degree to engage with music (Sloboda et al., 2001). If personal control is limited, the enjoyment of music decreases and the presence of background music may be met with irritation in a public environment (Krause et al., 2015; Sloboda, 2005; Sloboda and O’Neill, 2001). For instance, music is deemed the primary source of disruptive sounds by employers in malls (Alnuman and Altaweel, 2020).

Nevertheless, loud background music is imposed on people more than ever (Smith et al., 2000), and personal reasons for music listening often become irrelevant. One of the reasons underlying music in public spaces is to facilitate certain behaviors. It is known, for instance, that loud music makes drinks to be consumed faster (Stafford and Dodd, 2013), increases arousal, time and money spent on shopping (Bruner, 1990; Morrison et al., 2011), and distracts from body discomfort during high-intensity fitness classes (Yamashita et al., 2006). Additionally, North et al. (2004) reported that in approximately 74% of the cases when people were exposed to music, it was not their choice to put music on and there was no control over what and how loud it was played due to the exposure taking place in public environments, such as malls, shops, restaurants, bars, and gyms.

For a quantitative measure of the cumulative exposure to noise over a specific period we refer to the concept of noise dose, typically measured in decibels (dB) and hours. It accounts for both the intensity (loudness) and duration of noise exposure. The World Health Organization (WHO) guidelines suggest that noise exposure levels should remain below 70 dB over a 24-h period and 85 dB over a 1-h period to prevent hearing impairment (Śliwińska-Kowalska and Zaborowski, 2017). Taking the example of fitness classes, the sound pressure level can exceed 100 dB (Beach and Nie, 2014) even if disliked by the attendees (Beach and Gilliver, 2019), and in some cases may even induce a sudden sensorineural hearing loss (Kaul et al., 2019). Similarly, a recent study conducted by Scott (2018), found that 31% of restaurants and 60% of bars pose potential risks to people’s...
hearing health, with average sound levels of 77 and 81 dB, respectively.

Unwanted by the listener and bearing a potentially harmful effect due to the loudness and the length of exposure, music may fit the definition of noise. Noise is typically characterized as any sound that is unwanted, deemed undesirable, irritating, distracting, and discordant with one’s expectations, or that interferes with wanted sounds (Shepherd et al., 2015). Along with other types of noises, music is an environmental pollutant of the modern day and carries effects on one’s health and well-being, especially among susceptible individuals. This article provides a brief overview of the effects of unwanted music exposure (for a review of the effects of loud music on hearing, see Zhao et al., 2010). In addition, we put forward the consideration of individual variability in the tolerance for unwanted and loud sounds, and suggest policy improvements to reduce music as noise.

II. PREFERENCE FOR LOUD MUSIC

Individual variability in sound tolerance affects one’s relationship with music. There are individuals who seek louder volumes, while others tend to avoid situations where music is played loudly and feel discomforted by it. Preference for loud music is associated with personality traits such as extraversion and sensation seeking (Welch and Fremaux, 2017). For example, background music affects task performance differently for introverts and extraverts (Cassidy and MacDonald, 2007; Dobbs et al., 2011; Furnham and Srbc, 2002): while it maximizes outcomes for some, it can have a detrimental effect on the performance for others.

Among noise-sensitive individuals, hence people who exhibit increased reactivity to noise (Shepherd et al., 2019), background music is less commonly chosen for cognitive or emotional reasons compared to noise-tolerant individuals (Kliuchko, 2017). As a consequence, these individuals tend to spend less time using music to accompany other activities than noise-tolerant individuals (Franek, 2009; Kliuchko et al., 2015). However, playing music in the background is often the only option to gain control over one’s acoustic environment. Choice can then be considered one of the mediators of everyday musical behavior (North et al., 2004). People may indeed opt to listen to personal music players in different situations to help them mask sounds of transportation, crowd noises, and unwanted music when silence is not an available option. Furthermore, it has been shown that cognitive performance with background music is better than with office noises (Dobbs et al., 2011). Individuals may choose music to aid concentration and performance, even though it may disrupt certain tasks, such as reading comprehension (Thompson et al., 2012). In other words, music and other sounds may create a demand for the listener to ignore unwanted exposure or mask it. This vicious cycle is indeed concerning—an increasing amount of music in the environment demands more people to listen to music to avoid music and sounds that have externally been imposed on them. Further, conditioning by loud sounds and adaptation of the auditory system to high sound pressure results in a desire for even louder sounds (Welch and Fremaux, 2017). This link is further reinforced by positive experiences associated with loud but preferred and appealing music as well as by personality traits, e.g., wider activation maps to louder sounds is found in individuals with a higher trait “impulsivity” (Uppenkamp and Röhl, 2014). Last, since higher loudness may lead to higher chills experience (Bannister, 2020), which is considered an indicator of pleasure (for a review, see De Fleurian and Pearce, 2021), it is likely that loud music is preferred by individuals who derive significant pleasure from music listening. However, no study has yet investigated this potential association.

Beyond the role of individual differences, an additional factor is the diverse value attributed to music loudness in different cultures, where rhythms or melodies play a diverse role in communities and entertainment. For instance, in collectivistic societies, music plays a fundamental role in social bonding and is commonly employed as a social facilitator within social contexts (e.g., background music) (Boer et al., 2012). This might underlie a certain degree of accustomedness to the loudness of music. Conversely, in cultures where individuals tend to engage with music in introspective and intimate ways, such as individualistic societies, there might be a lesser inclination for high-volume musical settings (for a study exploring culture-specific uses of music see Boer and Fischer, 2012). These cultural differences might contribute to variations in music exposure attitudes and habits.

III. INDIVIDUAL DIFFERENCES IN NOISE SENSITIVITY

Several studies have reported a large variability among individuals’ susceptibility to noise and “noise trauma” (i.e., damage or injury to the auditory system caused by exposure to excessively loud sounds) (Cody and Robertson, 1983; Maison et al., 2013; Maison and Liberman, 2000), as well as the effects of noise on general health (van Kamp and Davies, 2013). Prolonged exposure to sounds above 85 dB can lead to noise-induced hearing loss or other auditory issues (Śliwińska-Kowalska and Zaborowski, 2017). Typically, a certain vulnerability is attributed to children and the elderly, as well as to different clinical populations, such as individuals who experience a partial or complete loss of the ability to hear sounds (for a review on groups highly exposed to noise-related risks, see van Kamp and Davies, 2013). On this matter, a cumulative body of research has also identified a link between neurodivergent conditions such as attention deficit hyperactivity disorder (ADHD) and autism, and heightened sensitivity to auditory stimuli (e.g., Gonen-Yaacovi et al., 2016; Kuiper et al., 2019). Moreover, personality traits, namely the set of behavioral, cognitive, and emotional patterns characterizing each individual, can determine person-related variations in susceptibility to adverse health outcomes from noise-exposure. Some people referred to as noise-sensitive, experience an
IV. CLINICAL HYPERSENSITIVITY TO SOUNDS

Over the years, several terms have been used to describe a clinical noise sensitivity to ordinary sounds that induce negative reactions. These terms include, inter alia, hyperacusis, hyperacusia, auditory hyperesthesia, auditory dysesthesia, odynacusis, phonophobia, increased noise sensitivity, collapsed tolerance level, and decreased sound tolerance, with the term hyperacusis used most frequently (Baguley and McFerran, 2011). Hyperacusis is a condition characterized by discomfort from loudness experienced at lower than average levels (typically 16–18 dB lower than what would be considered normal or comfortable for individuals without hyperacusis) (Baguley and Hoare, 2018; Sheldrake et al., 2015). This condition can exacerbate to the level where almost every ordinary sound is perceived as uncomfortably loud, unpleasant, frightening, or even painful (Tyler et al., 2014). As such, individuals with hyperacusis experience significant distress and impairment in social, occupational, and other daily activities (Aazh et al., 2016). The etiological mechanisms underlying this condition are unclear and complex. Indeed, although hyperacusis is an auditory disorder, Sheldrake et al. (2015) did not find any specific audiometric pattern associated with this condition, concluding that sensorineural hearing loss is not required for its development. The negative emotional reactions to sounds may also concern musical stimuli. Indeed, it has been suggested that hyperacusis also applies to recreational noise exposure, for instance, to loud music (Anari et al., 1999; Kähäri et al., 2003; Kähäri et al., 2004). Anari et al. (1999) reported that among 100 patients who reported an abnormal discomfort to sounds, the sounds were most likely to be music (31%). Moreover, hyperacusis has frequently been reported among musicians (e.g., Kähäri et al., 2003; Laitinen and Poulsen, 2008; Toppila et al., 2011), possibly in part due to their long exposure to high intensity sounds (Di Stadio, 2017).

Hyperacusis mainly depends on the physical characteristics of sound. This is because sound meaning and context are irrelevant in eliciting negative reactions (Jastreboff and Jastreboff, 2014). In contrast, the condition in which abnormally strong reactions occur to a sound with a specific pattern or meaning to an individual is called misophonia (Jastreboff and Jastreboff, 2002). In misophonia, patients experience involuntary overwhelming aggressive agitation (usually anger, irritation, or disgust) towards a person producing sounds associated with eating, such as crunching, chewing, or swallowing, and/or coughing, breathing, and other human generated sounds (Edelstein et al., 2013). The misophonic reaction can be extended to a wide and various range of trigger sounds, potentially including musical stimuli. Interestingly, music is not reported as a common misophonic trigger; however, on the contrary, it has been found to be the most used coping mechanism (Jager et al., 2020). Accordingly, music has been employed as a positive stimulus in the context of counterconditioning treatment for misophonia (Dozier, 2015).

V. HEALTH EFFECTS OF NOISE EXPOSURE

Excessive noise exposure is associated with auditory and non-auditory health effects (Basner et al., 2014). For instance, a prolonged sound between 75 and 85 dB can lead
to the loss of hair cells in the inner ear, which is irreversible and results in hearing loss (Basner et al., 2014). Peripheral hearing damage is a common consequence of loud sound exposure in occupational settings and, growingly, in leisure time where music plays an important role due to its widespread casual use (Lewis et al., 2013). Furthermore, exposure to loud leisure music can potentially influence the trajectories of age-related hearing loss (also known as presbycusis) (Kujawa and Liberman, 2006). In addition to the damage of peripheral hearing, it is recognized that noise has other effects on the central auditory system, such as compromised central speech processing, which can take place prior to any significant changes on a pure-tone audiogram (Kujala et al., 2004; Peretz et al., 2005). Among non-auditory effects of noise exposure on health and well-being are elevated stress, cardiovascular disease and hypertension, sleep disturbance, decreased cognitive performance, and annoyance (Basner et al., 2014; Munzel et al., 2014; van Kamp and Davies, 2013). Of these, sleep issues are considered the most detrimental short-term non-auditory effect of noise exposure, as sleep disturbance directly impacts individuals’ performance, quality of life, and health (Basner et al., 2014; Munzel et al., 2014). Long-term health effects of noise exposure include increases in systolic and diastolic blood pressure, changes in heart rate, and the release of stress hormones (Babisch, 2011; Basner et al., 2014), which may negatively affect the cardiovascular system.

Last, attending loud music venues or listening to personal music devices played at levels near the maximum output of the music device may result in a temporary threshold shift (TTS), namely, a temporary increase in hearing threshold sensitivity due to cochlear dysfunction, specifically affecting the inner and outer hair cells in the cochlea (Howgate and Plack, 2011). Although these changes appear to be reversible, temporary threshold shifts may predispose an individual to eventual permanent hearing loss (Chen et al., 2020). On this line, in a study on mice, Kujawa and Liberman (2009) found that after an exposition to 100 dB sound pressure level (SPL) noise for two hours, up to 50% of synapses between inner hair cells and auditory nerve fibers were destroyed, yet the absolute threshold remained unchanged. This phenomenon is known as cochlear synaptopathy, and despite several studies on the topic, evidence of this phenomenon in humans is still inconclusive (Prendergast et al., 2019). However, taken together these findings suggest that threshold sensitivity should not be seen as the only criteria to consider for quantifying noise damage in humans.

VI. CONCLUSIVE REMARKS & SUGGESTED POLICY IMPROVEMENTS TO REDUCE MUSIC AS NOISE

Music ranks among the greatest human pleasures (North et al., 2004; Zatorre, 2015). Music helps us to regulate our mood, can induce strong emotional responses, and makes us feel more connected with others (e.g., Cross, 2001; Juslin and Västfjäll, 2008; Mas-Herrero et al., 2013). However, it is common that we lack control over whether music is played, the kind of music being played, or the volume at which it is played. In all of these cases, music may be perceived as noise. For instance, rhythmic sports classes exploit music to enhance physical performance and reduce perceived exertion (for a review, see Terry et al., 2020), but the loudness falls out of one’s control and can be harmful. Variability in how individuals react to loud and unwanted music, as well as their susceptibility to its harmful effects on overall health, are crucial aspects to consider in research and prevention strategy development. Indeed, despite the objective measures of sound intensity, individuals experience their environments in different ways since the variability of sound perception in the general population is rather wide. The omnipresence of music has likely influenced us to adopt various listening approaches, including the capacity to listen passively (Krause et al., 2015), or even ignoring it completely. Ignoring loud background music, however, is not easily achieved by every individual and should not be taken for granted as a feasible way of coping with music in public spaces. One may argue that people who cannot easily tolerate the presence of music would then avoid activities that expose them to it. However, the near-ubiquity of loud music (e.g., Beach and Nie, 2014), and music in general, makes it difficult to avoid all situations where it is present without a negative influence on one’s personal life.

Research suggests that auditory sensitivities may significantly vary among individuals (Reybrouck et al., 2021). For instance, some individuals tend to experience discomfort that can lead to a perception of pain in response to generic and everyday sounds (hyperacusis), while others may exhibit increased reactivity due to a perceived noisy environment (noise sensitivity), or even a form of selective hypersensitivity to certain specific triggering sounds (misophonia). This highlights the importance of considering the impact of environmental noises while taking into account their meaning for the listener and the context in which they are perceived. In other words, due to the highly complex and subjective nature of potential music-related discomfort, it is necessary to consider the influence of additional cognitive and psychological factors, reaching beyond the merely acoustic aspects of the stimulus. For instance, individual sensitivity to musical pleasure, namely, an individual’s capacity to derive enjoyment and pleasant emotional responses from music (Mas-Herrero et al., 2013), may aid in identifying individuals for whom music might have a potentially greater positive or negative impact. On the one hand, individuals with higher levels of musical reward sensitivity might be more inclined to engage with loud, hence potentially harmful music, as loudness has been associated with higher chills experience (Bannister, 2020), although empirical proofs of this relationship are still missing. On the other hand, it is worth noting that for some people, music is not a pleasurable stimulus at all, regardless of its loudness. This phenomenon known as musical anhedonia has an estimated prevalence of 5%–10% among the general population (Mas-Herrero et al., 2014), and it is not ascribed to hearing and/or perceptual impairments (Martínez-Molina et al., 2016).

Accordingly, one of the objectives of this article is to point out that the potential discomfort arising from music
may extend beyond clinical populations or sensitive non-clinical groups, such as children and the elderly, but it can also affect a significant portion of the non-clinical population, e.g., HSPs and noise-sensitive individuals. In turn, loud and unwanted musical stimuli, hence perceived as noise, may trigger (or exacerbate) potential health issues, reaching beyond auditory concerns (Basner et al., 2014). The significant prevalence (e.g., noise sensitivity is estimated at 20%–40% in the general population), or even the mere existence of these sensitivities in the non-clinical population is largely disregarded. This oversight has prevented both affected individuals and policymakers from implementing the necessary strategies to recognize and address the issue.

To stop music from invading personal acoustic spaces we advocate levels of governmental regulations, as unlike other acoustic environment pollutants, music is the one with which we can actually and literally turn down the volume. The promotion of lower levels of noise and the need for silent spaces are not enough discussed, because often the people who actually consider music too loud are also people who think they are alone in perceiving this (Beach and Gilliver, 2019). This non-expressed opinion is prevalent (Beach and Gilliver, 2019); hence, it should be recognized and prevented. For those who crave silence, it should be more readily available in urban settings and, for those who crave loud sounds there should be better information on the negative effects of excessive loudness.

It would be hard to completely remove loud sounds and music from the environment since these are so inherent to modern life. However, international and national institutions should implement noise regulations that would also consider individual variations to tolerance of loud sounds and thereby standing by the side of hypersensitive individuals—or at least not neglecting—the citizens with special auditory processing dispositions, such as noise-sensitive or HSPs. The issue is more pertinent than ever, with the number of individuals exposed to high sound levels tripling since the 1980s (Smith et al., 2000), partly due to the proliferation of personal music players and the increased volume levels in restaurants and bars. For instance, a study conducted by Scott (2018), reported that the average dB for a New York restaurant is 77 dB, whereas for bars, it is 81 dB. Abercrombie & Fitch (A&F) stores play music ranging from 85 to 90 dB for marketing purposes, which is just below the legal limit permitted for commercial establishments with employees without ear protection (Biswa et al., 2019). Recently, Al-Arja (2020) reported that the sound level during 50 min of activity in gyms and fitness halls may range between 80 and 110 dB. In all of these cases, both employees and customers are potentially exposed to unsafe noise levels, as a prolonged sound between 75 and 85 dB is enough to induce the loss of hair cells in the inner ear (Basner et al., 2014). As such, these hazardous habits should not only be concerning for noise-sensitive individuals but should also be acknowledged within the general population.

To mitigate these risks, it may be beneficial to lower the current threshold of daily noise exposure applied to workplaces (i.e., 85 dB), especially in environments where background music is consistently played to affect performance or shopping behaviors, such as in gyms and shopping centers (Morrison et al., 2011; Terry et al., 2017). These new thresholds might be adjusted considering that the ideal sound level for normal conversation is from 55 to 65 dB (Kam et al., 1994), and that 55 dB has been proposed as an ideal sound level for shopping centers (Carvalho and Pereira, 2016).

In this perspective, sound level regulation is arguably even more important for music than for other stimuli due to the unique acoustic characteristics of music. Unlike other environmental sounds, music often contains repetitive rhythmic patterns and can be played at higher volumes for extended periods (Burger et al., 2012; Lu et al., 2004). This may partly explain why music is considered the primary source of noise-related annoyance in malls (Alnuman and Alataweel, 2020). Shopping malls, furthermore, are typically large and highly reverberant resulting in high noise levels that can harm both staff and customers. On this note, a further area of intervention should aim at improving acoustic design to enhance overall comfort and optimize acoustic parameters, including reverberation.

Among personal safe listening strategies, wearing earplugs represents an effective way to mitigate noise-related risks in recreational environments (Ramakers et al., 2016). Research on earplug use is mainly focused on young adults or hearing-impaired individuals (Hunter, 2017, 2018), but promoting their regular use for prevention among the general population can prove highly beneficial. To this end, in a qualitative study, Loughran et al. (2021) identified six specific key targets for behavior change interventions to improve earplug use: Social influences, environmental context, and resources, beliefs about consequences, memory, attention, and decision processes, emotion, and reinforcement.

An additional practical and easy suggestion may derive from the widespread availability of smartphone technology. Individuals now have access to digital sound level meters, such as SoundPrint application (“SoundPrint”), which enables rapid and real-time assessment of noise levels in public spaces, such as bars, restaurants, and gyms. By being aware of sound pressure limits and associated health risks, individuals can be encouraged to utilize these tools effectively. In addition, researchers, public health agencies, and local governments can leverage this data to monitor the impact of noise on hearing health and raise awareness about noise pollution (Scott, 2018). However, considering the high prevalence of noise sensitivities even among the non-clinical population, individual strategies (such as earplug use or smartphone technology) should be viewed as additional measures rather than as a substitute for policies aimed at creating a more noise-sustainable environment.

At the same time, raising awareness about the risks associated with loud music also benefits those who willingly choose to expose themselves to excessively high volumes on a regular basis. It is thought that nearly 40% of young and older adults aged 12–35 years from middle and high-income countries are exposed to potentially damaging sound...
levels in recreational venues such as nightclubs, discotheques, and bars (WHO, 2022). In fact, Williams et al. (2010) suggested that a sustained attendance to leisure facilities such as nightclubs and dance clubs may alone account to up to 60% of the total lifetime acceptable noise exposure. Mean sound levels in live music venues may vary from 103.4 dB for discotheque and rock concerts, to 96 dB for nightclubs (for a review, see Clark, 1991). These sound levels are way beyond the safety threshold conventionally set at 85 dB (Slawińska-Kowalska and Zaborowski, 2017), as only 15 min of exposure to 100 dB is enough to cause hearing damage (WHO, 2022). Therefore, it is less known that leisure sounds can easily reach levels that are higher than what people are exposed to at work, where the damaging effect of loud sounds (i.e., 85 dB) is generally accepted to be hazardous to health and the usage of hearing protection is regulated. However, very few countries mainly in Europe (e.g., Austria, France, Germany, Italy, Norway, Sweden) and some regions of North and South America provided specific policies and regulations to protect the hearing of audiences in entertainment venues. These regulations commonly include an upper sound level limit, real-time sound level monitoring, provision of earplugs, establishment of rest (quiet) zones, and provision of information/warnings. However, the specific requirements vary between countries, indicating a lack of standardization worldwide (WHO, 2022). On this line, a stricter regulation should also be introduced to moderate music exposure from personal listening devices, as it has been reported that the average listening level adopted by young adults ranges from 71 to 105 dB (Sulaiman et al., 2014). It could be appropriate to establish legal sound limits for personal listening devices, as in the case of France where the maximum output is set at 100 dB (Sulaiman et al., 2013). Noise-cancelling headphones have also proved effective as preventive measures for mitigating risks for users of personal music players (Liang et al., 2012).

In conclusion, with this article, we shed light on an aspect that is widespread and yet greatly underestimated. Music, which is originally intended to be a source of pleasure, may become a source of discomfort due to its intensity and/or forced exposure, leading to potential adverse effects both in terms of mental well-being and cognitive functioning. Our goal is to raise awareness among policymakers to implement appropriate measures in creating more adaptable auditory environments, and thus mitigate such a prevalent phenomenon. In this regard, we emphasize the importance of attributing greater consideration to individual differences in noise sensitivity, taking into account clinical populations (e.g., hyperacusis, misophonia), non-clinical populations (e.g., HSPs, noise-sensitive) as well as cognitive and psychological factors (e.g., sensitivity to music pleasure). Only by acknowledging these mechanisms can we achieve genuine progress in prevention strategies and interventions, ultimately leading to an acoustic environment that is suitable for individuals with diverse preferences and sensitivities.

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AUTHOR DECLARATIONS

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.


