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Sound thoughts: How understanding the teenage brain may help us look after their ears

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Neuroscience's study of brain structures and their function provides understanding of the biological underpinnings of behavior, including factors that may assist or act as barriers for programs designed to bring about behavioral change. This understanding can benefit how disease prevention and health promotion campaigns are developed and disseminated for greater effectiveness. Increasingly, public health campaigns have harnessed an understanding of neurobiology (and its complex interactions with social contexts and emotional and behavioral development of adolescents) and applied this knowledge to health promotion campaigns to enhance changed attitudes toward disease prevention and encourage healthy lifestyle choices (Bradshaw et al., 2012; Hall, 2016; Suleiman and Dahl, 2017; Pei et al., 2019).

While not an exhaustive list, some of the health focus areas that have incorporated neuroscience in their health promotion strategies include substance use (through understanding the strong association between substance use in adolescents and high levels of sensation seeking; Crawford et al., 2003), sexual health (via improved understanding of developing decision-making skills and the role of emotion and social influences; Ballonoff Suleiman and Brindis, 2014), and dietary health (by taking into account the neurobiological needs of safety and non-judgement; Debenham et al., 2022).

Together, these examples illustrate the importance of using our growing neuroscience knowledge about the susceptibility of risk taking, sensation seeking, and neuroplasticity in adolescence. These influences and their dynamic interplay with health conditions during this developmental phase make it an ideal time to implement positive, health-protective behavior. The consideration of neurobiological factors has been effective in increasing receptiveness to prevention messages that result in maximum engagement with young people and may be applicable across a range of health contexts and disciplines (Michie et al., 2011; Bradshaw et al., 2012; Meinke and Martin, 2017; Pei et al., 2019). One, as yet unexplored, area that may benefit from consideration is hearing health, in particular, the prevention of noise induced hearing loss (NIHL).

The impacts of hearing loss are well-documented to have far-reaching consequences that extend beyond listening and communication difficulties, impacting on personal, societal, and global levels if left untreated (Reed et al., 2019; Sheppard et al., 2020). The biological processes of how and when noise affects hearing is known—the risk of NIHL is based on the duration, frequency, and intensity of the noise exposure, regardless of the source (Clark and Bohne, 1999; Zhao et al., 2010), and so most prevention efforts are targeted at reducing the volume of sounds (i.e., reducing the risk at the source)

to which people are exposed because it is more feasible to implement. Lowering volumes reduces the risk of the source (a higher target for hierarchy of control) whereas changes to duration can be limited by the nature of the activity (for example, duration of concerts, physical fitness class is less amenable to change). Most countries have regulatory requirements and governance around occupational noise exposure as part of health and safety controls. However, managing recreational noise exposure is less straightforward.

Occupational noise regulations apply regardless of the noise source (machinery or music) however, these are only directed at employees rather than attendees. Even then questions have been raised as to the effectiveness of these for music venues, and adherence by such workplaces to the regulations; (Barlow and Castilla-Sanchez, 2012; Kelly et al., 2012; World Health Organization, 2022).

For non-occupational exposures, it is difficult to develop regulations that take into account the wide range of possible high-volume recreational activities and individual variation in participation.

As a result, recreational noise exposure remains highly dependent on the choices made by individuals about what activities they participate in, for how long, and whether they choose to take any precautions to reduce the risk to their hearing.

As individual behavior remains a major determiner of the risk to hearing from noise, prevention activities aim to motivate and encourage engagement with noise-reduction. The cumulative nature of NIHL means that there is merit in focussing attention on the noise exposure behaviors of young people, with WHO estimates that more than one billion young people (aged 12–35 years) are at risk of hearing loss due to recreational exposure to loud sounds (2022). Recreational NIHL is preventable, its consequences are as detrimental comparative to occupational NIHL, and it should be made a public health priority (Murphy et al., 2018; Pienkowski, 2021). However, noise-induced hearing loss may not be detectable or treatable during adolescence given the cumulative nature of hearing damage (Williams and Carter, 2017). Thus, this opinion piece focusses on prevention efforts that aim to reduce the risks to hearing over time.

Adolescence is a period marked by physical change and neural development and one which also encompasses identity formation and social growth that extends from 10 to 24 years (Sawyer et al., 2018). This formative time in the life course is also associated with skill learning, exploration, and risk-taking behaviors that could promote wellbeing (such as relationship building, shifts in sociocultural perspectives, and greater peer and societal engagement). Yet, adolescents may also be vulnerable to risk-taking and sensation seeking and forming negative behavioral patterns can also lead to adverse outcomes that heighten health risks (such as substance use and engaging in risky behaviors, among others) which could increase the burden of disease in later decades of life (Suleiman

and Dahl, 2017; Patton et al., 2018; Pei et al., 2019). There has, therefore, been an increasing global focus on health of adolescents (currently the largest population in human history) recognizing that appropriate health investments are needed to ensure that future generations can thrive (Patton et al., 2018).

Historically, NIHL efforts focus on hearing health education and awareness building, but there is evidence to suggest that these have been limited in their effectiveness to change behavior, shift cultural norms, or improve rates of using hearing protective devices (Weichbold and Zorowka, 2007; Vogel et al., 2008; Widén, 2013; Gilles, 2014; Keppler et al., 2015; Steinberg, 2015). Prevention of noise-induced hearing loss for adolescence should aim to set up good habits to listen safely well into future when noise risks often start to increase. As the biggest risk is often from noise exposure that is specifically sought out in leisure activities, efforts aiming to reduce rather than avoid or ban noise might be most feasible. Thus, the challenge for this population is to foster or promote a positive habit to seek out sound safely that could facilitate safe sensation-seeking. Whilst it may be possible to educate adolescents to avoid extremely loud situations where acoustic shock symptoms are obvious and immediate signs of damage, much of prevention work is targeted at more subtly risky situations where damage may occur unnoticed.

Progressively, there has been greater attention on utilizing theoretical underpinnings grafted from behavior change principles to assist researchers and clinicians in better understanding hearing health behavior change. Through this, we can broaden how we conceptualize young people's attitudes, beliefs, intentions, and motivations tailor interventions that promote hearing health behavior changes (Coulson et al., 2016). But in addition to behavior change and health promotion models, our increasing understanding of neurobiology during adolescence may provide further dimensions to how to promote and foster healthy hearing behaviors. In particular, it is worth considering two significant factors associated with adolescence—sensation seeking and social influence.

Brain areas responsible for processing reward sensitivity have shown to be hyperactivated in young adults engaging in risk-taking behaviors (Telzer et al., 2014; Qu et al., 2015). This sensation-seeking appeal is further positively reinforced by peer influence. The quality of peer relationships is crucial as it can have a positive buffering effect (that serves as a protective behavior), or increase stress, thus increasing risk-taking behaviors that negatively impact health (Galván, 2013).

Such mechanisms may explain the commonly seen disconnect between knowledge of noise-exposure risks and preventative action. Despite awareness of risks, research has frequently shown individuals choosing to participate in noisy activities, and/or declining opportunities to mitigate that risk through hearing protection activities. Social norms have been implicated in young people's decisions about personal music player listening behaviors (Gilliver et al., 2012) and rejection of earplugs at music venues (Beach and Gilliver, 2019).

Sensation-seeking, too, has been noted as an important factor for music-listening. An investigation of young people (18–25 years) by Welch and Fremaux (2017) found that enjoyment of loud sounds at music venues was related to enabling positive physical and social experiences. The physical sensation of loud music heightens emotions and arousal state, masks negative emotions, and removes inhibitions. To this end, loud music and sounds promote intimacy and social identity and further emphasize the desire to adopt or adhere to social norms.

Taken together, this has implications when considering interventions that target recreational NIHL during adolescence. If the neurobiology of adolescents and young adults is dominated by social bonds, peer influence, and heightened risk-taking behaviors, then current approaches to hearing conservation campaigns that simply aim to provide knowledge and educate the harmful effects of loud noise stemming from recreational activities are incongruent with the needs of the target audience.

A transdisciplinary approach is necessary to develop health promotion programs. Researchers, public health policy decision-makers, health practitioners, and the education system are required to work collaboratively to harness the ways in which neurobiology interacts with socio-contextual factors to order to inform effective health campaigns that are meaningful and age-appropriate (Beach, 2017; Meinke et al., 2017; Beach and Gilliver, 2019). Neuroscience-informed approaches to tackling adolescent health issues should be seen as complementary to existing behavioral and more traditional approaches to disease prevention and health promotion. The premise of this innovative approach has shown to be successful at informing and educating young people, and de-stigmatizing health conditions while promoting tolerance and understanding of (neuro)biological limitations of the adolescent brain (O'Connor and Joffe, 2013).

Summary and future directions/discussions

Adolescence is a formative period in life with a dual nature of vulnerability to risks and adaptability as an opportunity to form life-changing, health-promoting habits. With the rising number of young people at risk of recreational NIHL, there is a need for more effective ways to address this issue. The known

social aspect of recreational noise experiences and the power of sensation-seeking of the adolescent brain warrants further exploration and consideration in NIHL prevention campaigns.

The application and contributions of neuroscience to inform future NIHL prevention programs for this age group will make a novel, meaningful, and innovative pursuit. It also presents an opportunity for neuroscientists who research adolescent health behaviors to explore an—as yet uncharted area of research.

Neuroscience-informed approaches to reducing recreational NIHL for young people are required to meet the needs of the developing adolescent brain. Designing age appropriate NIHL campaigns that take these factors into account may assist to increase the likelihood that interventions are efficacious and cost-effective.

Author contributions

JP and MG contributed to the conception and subsequent preparation of this manuscript. Both authors contributed to the article and approved the submitted version.

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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.

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