Clinical Neurophysiology 129 (2018) 1254–1267

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Neural and behavioral changes after the use of hearing aids

Hanin Karawani [a,*], Kimberly A. Jenkins [a,b], Samira Anderson [a,c]

[a] Department of Hearing and Speech Sciences, University of Maryland, College Park, MD, USA
[b] Walter Reed National Military Medical Center, Bethesda, MD, USA
[c] Neuroscience and Cognitive Science Program, University of Maryland, College Park, MD, USA

ARTICLE INFO

Article history:
Accepted 23 March 2018
Available online 7 April 2018

Keywords:
Amplification
Hearing aids
Frequency-following response
Older adults
Hearing loss
Age-related hearing loss

HIGHLIGHTS

- Hearing aid use may offset delays in neural timing associated with hearing loss.
- Hearing aid use may reduce over representation of the temporal envelope.
- Satisfaction with hearing aids increases over the course of six months.

ABSTRACT

Objective: Individuals with age-related hearing loss (ARHL) can restore some loss of the auditory function with the use of hearing aids (HAs). However, what remains unknown are the physiological mechanisms that underlie how the brain changes with exposure to amplified sounds though the use of HAs. We aimed to examine behavioral and physiological changes induced by HAs.

Methods: Thirty-five older-adults with moderate ARHL with no history of hearing aid use were fit with HAs tested in aided and unaided conditions, and divided into experimental and control groups. The experimental group used HAs during a period of six months. The control group did not use HAs during this period, but were given the opportunity to use them after the completion of the study. Both groups underwent testing protocols six months apart. Outcome measures included behavioral (speech-in-noise measures, self-assessment questionnaires) and electrophysiological brainstem recordings (frequency-following responses) to the speech syllable /ga/ in two quiet conditions and in six-talker babble noise.

Results: The experimental group reported subjective benefits on self-assessment questionnaires. Significant physiological changes were observed in the experimental group, specifically a reduction in fundamental frequency magnitude, while no change was observed in controls, yielding a significant time $\times$ group interaction. Furthermore, peak latencies remained stable in the experimental group but were significantly delayed in the control group after six months. Significant correlations between behavioral and physiological changes were also observed.

Conclusions: The findings suggest that HAs may alter subcortical processing and offset neural timing delay; however, further investigation is needed to understand cortical changes and HA effects on cognitive processing.

Significance: The findings of the current study provide evidence for clinicians that the use of HAs may prevent further loss of auditory function resulting from sensory deprivation.

1. Introduction

Older adults often experience significant difficulties understanding speech in non-favorable conditions, such as noisy or multi-talker environments (e.g., Pichora-Fuller et al., 1995; Schneider and Pichora-Fuller, 2001). These difficulties are often exaggerated by age-related sensorineural hearing loss (Fitzgibbons and Gordon-Salant, 2010), which is known to be one of the most prevalent health conditions among the elderly (Yueh et al., 2003). Given the communication difficulties experienced by older adults with hearing loss, is it possible for them to at least partially regain loss of auditory function? Several rehabilitation

* Corresponding author at: Department of Hearing and Speech Sciences, 0100 Lefrak Hall, 7251 Preinkert Drive, College Park, MD 20742, USA.

E-mail address: karawani@umd.edu (H. Karawani).

https://doi.org/10.1016/j.clinph.2018.03.024
1388-2457/

processes have been applied in research, such as counseling or patient-centered education, auditory training, and the provision of hearing aids. Hearing aids increase audibility and are currently the primary rehabilitation option for individuals with mild to moderately severe sensorineural hearing loss. Auditory training may also improve listeners' communication and compensate for the degraded auditory signal (Sweetow and Palmer, 2005; Stecker et al., 2006; Sweetow and Sabes, 2006; Sweetow and Sabes, 2007, Sweetow and Henderson Sabes, 2010, Anderson et al., 2013c; Lavie et al., 2013; Olson et al., 2013; Ferguson et al., 2014; Karawani et al., 2016). However, signal audibility through the use of hearing aids is the first requirement for any training program to be effective.

Extensive research has documented the widespread benefits of the hearing aid rehabilitation process (Plomp, 1978; Fujikawa and Owens, 1979; Davis and Haggard, 1981; Humes, 1991; Jerger et al., 1996; Munro and Lutman, 2003; Lavie et al., 2014; Lavie et al., 2015). Generally, this research shows benefits of the use of hearing aids in easy listening conditions (Shanks et al., 2002), and in communication abilities and quality of life (Chisolm et al., 2007; Takahashi et al., 2007). However, evidence supporting auditory acclimatization with hearing aids – "the process in which hearing aid users become gradually accustomed to amplification" (Gatehouse, 1992, page 1258) – has been inconsistent, and the extent to which the auditory system adapts to new input remains unknown. For example, studies with unilateral hearing aid fittings demonstrated improved speech recognition in noise that was specific to the aided ear (Gatehouse, 1992; Munro and Lutman, 2003). Another study with unilateral hearing aid fitting demonstrated that experienced hearing aid users could improve performance in noise after hearing aids were set to new frequency responses, but these responses required eight to sixteen weeks for acclimatization to the new fitting (Gatehouse, 1993). Lavie et al. (2015) compared acclimatization effects to amplification in the dominant vs. nondominant ear (based on dichotic performance) and to bilateral amplification. They found improvement in performance on speech identification in noise and dichotic listening tasks, but the benefits were seen mainly for the nondominant ear and in unaided conditions. Summarizing early evidence of perceptual and neural changes, Munro (2008) concluded that hearing aid experience from monaural fitting can modify processing of the auditory system.

However, evidence of acclimatization after binaural hearing aids has not yet been demonstrated. Specifically, Humes and Wilson (2003) tracked changes in hearing aid performance and benefit in nine elderly binaural hearing-aid wearers over a three-year period following the hearing aid fitting. Little evidence of systematic improvement in aided performance or benefit was noted. A more recent study of new unilateral and bilateral hearing aid users and experienced hearing aid users found small gains in speech recognition across the three groups that were consistent with a practice effect (Dawes et al., 2014a). The reasons for differing evidence of acclimatization to unilateral and bilateral fittings are unknown, but perhaps the unilateral fitting induces greater reliance on the aided ear with consequent changes in perceptual performance.

Individual capacity for perceptual learning may also be a factor in acclimatization. Hearing aid users may differ in their ability to adapt to amplified speech; therefore, differences in perceptual learning might explain variability in improved performance with hearing aids over time (Gatehouse, 1993; Robinson and Summerfield, 1996). The capacity for auditory learning may be affected by maladaptive changes in the central system that accompany aging and hearing loss, thus limiting potential hearing aid benefits (Arlinger et al., 1996; Irvine et al., 2001). Even with optimally fit hearing aids, users often complain about difficulties with word recognition and speech understanding, especially in the presence of background noise or other competing stimuli (Kochkin, 2000; Gordon-Salant, 2005) or in reverberant conditions (Bender et al., 1993; Van Tasell, 1993). These deficits may arise from age-related declines in temporal auditory processing. In particular, the ability of neurons in the central auditory system to accurately encode important temporal features of speech may be limited by impaired neural synchrony (Sergeyenko et al., 2013), delayed neural recovery (Walton et al., 1998), reduced phase locking (Parthasarathy et al., 2014), or other mechanisms associated with aging. These problems are exaggerated by the presence of sensorineural age-related hearing loss. Age-related hearing loss may alter spatial and temporal response properties in the auditory system (Willott et al., 1991; Irvine et al., 2001), which interferes with the gain mechanism of the auditory cortex (Morita et al., 2003; Wienbruch et al., 2006). The effects are especially salient when the target speech stream is masked by background noise (Anderson et al., 2013a). Hearing aid amplification results in stimulation of the auditory pathways that have been altered by auditory deprivation, and in some individuals, by processes associated with aging. In addition, hearing aids significantly modify the physical characteristics of sound, which may explain why adjusting to new hearing aids requires time and practice (Watson, 1991; Robinson and Summerfield, 1996; Tyler and Summerfield, 1996).

Taken together, it is still not clear whether the use of hearing aids can drive beneficial plastic changes in perceptual functions that are relevant to speech understanding in non-optimal listening conditions. In addition, the neural mechanisms that are derived by the use of hearing aids are still unknown. Finally, if neural changes do occur, what are the physiological mechanisms that underlie the changes induced by use of hearing aids?

A few electrophysiological studies in older adults have assessed amplification effects on subcortical (Anderson and Kraus, 2013; Easwar et al., 2015; Jenkins et al., 2017) and cortical (Van Dun et al., 2016; Jenkins et al., 2017) auditory regions at the time of hearing aid fitting. Jenkins et al. (2017) recorded frequency-following responses (FFRs) and cortical-auditory evoked potentials to a speech syllable /ga/ presented through a speaker. The FFR results demonstrated higher phase locking, earlier latencies, and higher amplitudes to the transition region of the speech syllable in aided vs. unaided conditions. The cortical results showed that amplification resulted in earlier latencies and increases in amplitude. Easwar et al. (2015) also investigated aided and unaided FFRs using direct audio input of a male-spoken token /susaʃi/ representing a wide range of frequencies in older listeners with hearing loss. Amplification resulted in increased detectability and amplitude of the response. Widening the hearing aid bandwidth from a low-pass filter cutoff of 1 kHz up to 4 kHz increased detectability, suggesting that the FFR may be used to verify audibility and to evaluate the effects of manipulating hearing aid parameters.

Increased audibility with amplification in older adults with hearing loss was also demonstrated with cortical potentials with higher P1-N1 amplitudes in amplified vs. unamplified testing conditions for stimuli presented at low and moderate levels (Van Dun et al., 2016). Korczak et al. (2005) also used cortical evoked potentials to test amplification effects in younger adults with sensorineural hearing loss and found that amplification by the use of personal hearing aids substantially improved the detectability of all the cortical peaks. These studies show that amplified stimuli results in better neural encoding of the amplified speech signal because of the improved audibility that is available immediately after amplification. However, other cortical studies in normal-hearing young adults (e.g. Billings et al., 2007; Billings et al., 2011) revealed no changes in cortical auditory evoked potential