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The effect of a simulated hearing loss on performance of an auditory memory task in driving

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ABSTRACT

Hearing loss has been shown to exacerbate the effect of auditory distraction on driving performance in older drivers. This study controlled for the potentially confounding factor of age-related cognitive decrements, by applying a simulated hearing loss in young, normally hearing individuals. Participants drove a simulated road whilst completing auditory tasks under simulated hearing loss or normal hearing conditions. Measures of vehicle control, eye movements and auditory task performance were recorded. Results showed that performing the auditory tasks whilst driving resulted in more stable lateral vehicle control and a reduction in gaze dispersion around the road centre. These trends were not exacerbated by simulated hearing loss, suggesting no effect of hearing loss on vehicle control or eye movement patterns during auditory task engagement. However, a small effect of simulated hearing loss on the performance of the most complex auditory task was observed during driving, suggesting that the use of sound-based in-vehicle systems may be problematic for hearing impaired individuals. Further research incorporating a wider variety of driving scenarios and auditory tasks is required in order to confirm the findings of this study.

1. Introduction

The effect of hearing loss on driving performance has been largely neglected in the road safety literature, perhaps because of the overwhelming reliance of driving on the visual modality (Sivak, 1996). Indeed, there is a wealth of research which has investigated the effect of visual sensory impairments on driving (see e.g. Owsley & McGwin, 2010 for a review), with a number of associated assessment techniques which can be used to identify at risk drivers. For example, the Useful Field of View test (Ball & Owsley, 1993) has shown a correspondence with measured driving performance and accident rates (Clay et al., 2005). However, only a handful of studies have looked at the effect of hearing impairment on driving performance, road traffic accidents, and driving cessation rates (Herbert, Thyer, Isherwood, & Merat, 2016). Much of the work in this area has been observational in nature, and the outcomes are heterogeneous, often because important variables such as annual mileage or driving experience are not controlled. Furthermore, these studies typically use self-reported measures of functional hearing loss, which may be problematic for drawing firm conclusions, as they can be subject to extraneous influences such as changes in cognitive and psychological factors (Salonen, Johansson, Karjalainen, Vahlberg, & Isoaho, 2011).

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Whilst some hearing loss and road safety research shows an increased risk of road traffic accidents in hearing impaired individuals, it does little to explain why driving decrements may occur as a result of hearing impairment. The literature has largely been speculative, with some authors suggesting that hearing impaired individuals are unable to hear driving-relevant auditory information (Picard et al., 2008), and others suggesting that audible auditory information is more distracting for individuals with a hearing loss than those with normal hearing (Hickson, Wood, Chaparro, Lacherez, & Marszalek, 2010).

There is little empirical evidence to support the suggestion that hearing impaired individuals are unable to hear driving-relevant sounds, although there has been some research investigating the distracting effect of audible information in hearing impaired drivers. For example, Hickson et al. (2010) asked older, normally hearing and hearing impaired individuals to drive a closed-road circuit whilst performing concurrent auditory and visual tasks. Their aim was to establish if sensory hearing loss increases the cognitive resource requirements of listening, thus partly removing capacity that could be used for other concurrent processes required for safe driving. The authors found that, compared to normally hearing participants, hearing impaired drivers were significantly less likely to recognise road signs, and showed an overall poorer driving performance (as indicated by a composite score of road sign recognition, gap perception, course completion time, and the number of road hazards hit) when required to complete an auditory task. Hickson et al. (2010) concluded that hearing impaired individuals should limit their engagement with in-vehicle devices, to ensure their driving safety is not affected. However, these conclusions should be treated with some caution as the authors' sample included only older hearing impaired individuals, aged between 62 and 88 years and the influence of age-related factors on performance cannot be excluded from these results.

An interesting, and unexpected, outcome of the Hickson et al. study (2010) was that hearing impaired individual's driving performance (indexed by their composite driving score) was also affected to a greater extent than their normally hearing counterparts by visual task engagement, although the authors offer little explanation for this finding. Similar results were observed in a study by Thorslund, Peters, Lidestam, and Lyxell (2013), where hearing impaired individuals exhibited a more marked change in driving behaviour than a normally hearing sample when completing a visually-presented in-vehicle task during driving. When hearing impaired drivers were asked to repeat back four visually-presented letters, their braking and evasive actions (such as passing a parked vehicle) were found to be affected, with slower speeds adopted by this group of drivers compared to the normally hearing sample. The authors suggested that cognitive resources were diverted from the driving task to the visual task for hearing impaired participants, because they require more explicit processing to perform lexical tasks due to the degradation of auditory representations in long-term memory (Andersson, 2002; Rönnberg, Rudner, Foo, & Lunner, 2008). However, since the mean age of the groups recruited for the Thorslund, Peters, Lidestam et al. (2013) study ranged between 60 and 62 years, it is also possible that their dual task performance was actually affected by an age-related decline of cognitive resources, rather than as a direct result of hearing loss. This argument is compatible with a common-cause hypothesis which suggests that sensory impairment is a marker of global cognitive decline (Li & Lindenberger, 2002), and is supported by studies which have reported a higher prevalence of cognitive decline in hearing impaired individuals (e.g. Baltes & Lindenberger, 1997). Overall these studies indicate an urgent need to explore the relationship between hearing loss and cognitive decline and the effect on driving performance, to allow a better understanding of the factors underpinning the driving abilities of hearing impaired people.

The aim of this study was to remove the effect of age-related cognitive decline on driving performed during concurrent auditory tasks, by presenting digitally processed auditory stimuli which simulated hearing loss to a sample of young, normally hearing drivers. The method of hearing loss simulation used has been shown to approximate the loudness, dynamic range and frequency selectivity of 'real' hearing impairment (Baer & Moore, 1994; Moore & Glasberg, 1997; Nejime & Moore, 1997). The rationale for using this method was partly due to difficulties in recruiting an adequate sample of young hearing impaired drivers for this study, but also to ensure that cognitive impairment was not a confounding factor. The research questions posed were:

(1) Does auditory task engagement whilst driving lead to any changes in driving performance?
(2) Does the difficulty of the auditory task being performed alter these effects on driving performance?
(3) When auditory stimuli used in these tasks are presented in a simulated hearing loss condition, are the effects on driving performance further changed?
(4) Is there a difference in auditory task performance between the normal hearing and simulated hearing loss conditions whilst driving?

2. Method

2.1. Participants

36 young, normally-hearing participants (16 female; 20 male) were recruited from the University of Leeds Driving Simulator (UoLDS) participant database. The sample was aged between 20 and 40 years and had a mean age of 28.3 (S.D. = 5.7) years. Participants had 1–22 years of driving experience, with a mean of 9.5 (S.D. = 6.3) years, and drove an average 6900 (S.D. = 4400) miles per year. Participants were screened for normal hearing (absolute thresholds of $\leqslant$20 dB HL at frequencies of 0.25, 0.5, 1, 2, 4 and 8 kHz in both ears) using pure tone audiometry (British Society of Audiology, 2011) and were reimbursed £15 for taking part in the experiment. Ethical approval was granted for this study by the University of Leeds AREA Faculty