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The impact of age-related hearing loss and lateralized auditory attention on spatiotemporal parameters of gait during dual-tasking among community dwelling older adults

Marta Maria Gorecka[a], Olena Vasylenko[a], Jacob Espenes[a], Knut Waterloo[a,b], Claudia Rodríguez-Aranda[a,*]

[a] Department of Psychology, University of Tromsø, Norway
[b] Department of Neurology, University Hospital North Norway, Tromsø, Norway

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ABSTRACT

This investigation assessed the impact of hearing loss and lateralized auditory attention on spatiotemporal parameters of gait during overground dual-tasking by the use of the dichotic listening task. Seventy-eight right-handed, healthy older adults between 60 and 88 years were assigned to a Young-Old (< 70 years) or an Old-Old (> 71 years) group. Cognitive assessment and pure tone audiometry were conducted. Spatiotemporal parameters of gait quantified by mean (*M*), and coefficient of variations (CoV) were evaluated with the OptoGait system during 3 dichotic listening conditions: Non-Forced, Forced-Right and Forced-Left. Factorial analyses of variance and covariance were used to assess group differences and the moderating effects of hearing status, respectively. Results demonstrated that three of the gait parameters assessed were affected asymmetrically by the dual-task paradigm after controlling for hearing status. Asymmetries existed on step width, gait speed and variability of stride length. Finally, correlations between gait outcomes and dichotic listening results showed that *M* and CoVs in gait parameters during right-ear responses were longer compared with left-ear. Left-ear responses were related to increased variability on stride length, which indicates higher difficulty level. Hearing status varying from normal to mild levels of hearing loss modulates spatiotemporal gait outcomes measured during dichotic listening execution. Findings suggest that attending to left side stimuli relates to increased gait variability, while focusing on right-side assures a safe walk. Results demonstrated that attending to right-ear stimuli is an adaptive strategy for older adults that compensates for limited sensorimotor and cognitive resources during walking.

1. Introduction

The “dual-task paradigm” has been broadly employed to study aging effects on multitasking, and more specifically, on the interplay of gait and cognition. This paradigm is used to disentangle the possible causes of falls in older populations. Notwithstanding, there are some caveats. One is the absence of appropriate rationale for the selection of the cognitive tasks challenging gait. Since type of cognitive task used during walking matters (Beauchet et al., 2005), tests measuring specific cognitive mechanisms that can be naturally adapted on dual-tasking should be prioritized. A second limitation is the lack of information about the role of sensory loss influencing the gait-cognition association. To our knowledge, the very common condition of age-related hearing loss among older adults over 60 years has not yet been explored in dual-task investigations.

Age-related hearing loss (ARHL) or presbycusis is a chronic, degenerative condition following accumulating extrinsic and intrinsic factors resulting in impairments in cochlear transduction of acoustic signals (Huang and Tang, 2010). ARHL is also one of the most prevalent chronic conditions in the older population (Yamasoba et al., 2013). As it is well established, ARHL aggravates with increasing age and it goes hand by hand with declined cognition (Lin et al., 2011a). It is calculated that 37% of older persons between 60 and 70 years have a hearing loss over 25 dB, while the proportion elevates to 60% among those over 70 years (Van Eyken et al., 2007). Whether ARHL and cognitive decline arise due to a common etiology or as a result of a direct link between the two phenomena (Wayne and Johnsrude, 2015) is still a matter of debate. Nonetheless, hearing loss and cognitive deficits co-exist in the older adult and both conditions have been associated with impaired

* Corresponding author at: Department of Psychology, University of Tromsø, N-9037 Tromsø, Norway.
E-mail address: claudia.rodriguez-aranda@uit.no (C. Rodríguez-Aranda).

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functional status (Chen et al., 2015) and increased risk of falls (Lopez et al., 2011). To our knowledge, there are only two earlier studies addressing the issue of hearing loss and dual-tasking (Lau et al., 2016; Bruce et al., 2017).

Because hearing loss is closely connected to cognitive decline in aging and it also affects walking and balance (Lin et al., 2011b) it is important to take the condition into account in dual-task studies. A central interest is to understand the relevance of sensorimotor changes due to aging when walking, listening and talking occur concurrently. In fact, such a scenario has been addressed under experimental conditions using the dichotic listening test (DL) (Decker et al., 2013; Decker et al., 2017). DL is a robust task for the study of divided attention and executive function in which participants need to attend to specific auditory information during trials where competing stimuli are simultaneously applied to both ears. During three conditions subjects are required to report information based on a self-selected choice or from one specific ear. DL tests hemispheric lateralization of language and the fact that the brain mechanisms underlying DL performance are well-known is of great interest for dual-task research. The benefit of the test is its ability to assess attention across different levels of task difficulty as well as possible asymmetrical effects on gait due to lateralized focus of attention.

1.1. Why does lateralized focus of auditory attention influence gait asymmetrically?

In order to answer this question, we need to address the topic of hemispheric specialization in aging and specifically in DL and gait. With increasing age, hemispheric specialization tends to diminish as observed in functional imaging studies (Cabeza, 2002). However, hemispheric specialization is differently affected by age depending on the cognitive modality or function under consideration. For instance, during performance of the DL test, right-handed older adults demonstrate larger difficulties to report stimuli from left-ear while their ability to report from right ear is more accentuated (Stecker et al., 2015). The preference for right-ear stimuli is a phenomenon called “the right ear advantage”, which exists in all right-handed subjects and is explained by the left-hemispheric dominance for language processing (Hugdahl, 1988). In contrast, processing of left-ear stimuli is more challenging as information coming from left-ear is transmitted via the anatomical decussation of fiber pathways to the right hemisphere. There, the signal has to be further transferred through corpus callosum to the left hemisphere for final processing (Hugdahl et al., 2008). Thus, the difficulty to report stimuli from left-ear in aging is thought to be caused by decreased inter-hemispheric transfer of the auditory input, probably due to size reduction of the corpus callosum (Westerhausen et al., 2015).

Concerning the effects of aging on lateralized organization of motor functions, findings depend on the action in question. For example, in upper-limb function preservation of lateralized capacities has been documented (Sebastjan et al., 2017). As for walking, the situation is quite different. In healthy individuals gait is a rather symmetric function (Viteckova et al., 2018), controlled by basic spinal motor programs that keep movement synchronization (Ivanenko et al., 2006). However, under specific contexts like in dual-tasking, the nervous system needs to integrate additional sensorimotor information by utilizing higher-level cortical functions and volitional actions. These events perturb central generator patterns for locomotion (Ivanenko et al., 2006; Robinson and Kiely, 2017). In aging, walking becomes a more demanding action and more involvement of executive functions and attention is required (Yogev-Seligmann et al., 2008). Thus, additional cognitive loading in dual-tasking further disturbs gait patterns.

In the past, few studies have evaluated the effects of the concomitant cognitive task on gait asymmetries in healthy older adults, probably because asymmetries are regarded as a pathological feature (Yogev et al., 2007). One of these studies evaluated gait asymmetries by the use of a verbal fluency test (Dalton et al., 2016), but data only showed a trend towards disrupted asymmetry. In another recent investigation, arm swing asymmetries in healthy older adults have been reported during execution of a dual-task employing the Stroop test (Killeen et al., 2017). Authors of this study remark the absence of information about asymmetric effects for lower limbs, implying that gait asymmetries might not arouse by dual-tasking in healthy populations. However, this is still an open question as for now, most of the cognitive tests adopted in dual-task research do not deliberately assess lateralized cognitive functions. Therefore, in the present study we used the DL test, which increases cognitive load in a lateralized way. Since DL performance recruits higher attentional resources on one brain hemisphere (Tervaniemi and Hugdahl, 2003), a lateralized cortical activation during DL is superimposed to motor programmes acting on both sides of the corticospinal pathway that control both sides of the body. Hence, it is reasonable to expect that lateralized focus of attention will disrupt coordination of these motor programmes asymmetrically.

1.2. Interest of the present study

The use of DL as a secondary task has only been investigated during walking on a treadmill (Decker et al., 2013; Decker et al., 2017). Because it is well documented that walking on a treadmill modifies the way in which participants ambulate (Hollman et al., 2016), findings from these studies cannot generalize to normal walking, it is necessary to assess DL in dual-tasking during overground walking. In addition, gait studies using treadmills augment the attentional requirements as achievement of a steady walk on the device increases the cognitive load and subjects tend to prioritize walking at the expense of the secondary task (Regnaux et al., 2006). This means that the effects exerted by DL need to be investigated on regular walking, especially concerning older adults for whom just walking already demands increased cognitive control (Yogev-Seligmann et al., 2008). For these reasons, it is important to evaluate DL as a secondary task during walking overground, which will bring an optimal ecological valid environment that resembles daily situations. Therefore, the aim of the present study was two-fold: First, evaluate possible asymmetric effects of DL in a dual-task paradigm during walking overground in right-handed healthy older adults and secondly, to assess the moderating effects of hearing loss on this experimental situation.

2. Method

2.1. Participants

Seventy-eight right-handed volunteers ranging in age between 60 and 88 years ($M = 71.1$, $SD = 6.6$) participated in the dual-task study. All the participants were involved in a larger umbrella project of motor functions and cognition at our institution. Only right-handed individuals were enrolled as it is demonstrated that left-handed people present atypical lateralization patterns (Westerhausen et al., 2015). Because specific age ranges of older adults may have an impact on study results (e.g., Ihle et al., 2016), participants were assigned to a Young-Old group (YO, ≤ 70, $n = 38$) or to an Old-Old group (OO, ≥ 71, $n = 40$). This approach has been adopted by numerous investigations, and it assures inclusion of specific age-ranges of older adults with different levels of hearing loss and cognitive deficits. Educational level of the whole group was 13 years on average ($SD = 3.9$), 72% of the participants were retired and 56% were females. All individuals were community living older adults from north-Norway, free of major diseases or cognitive troubles. Inclusion criteria were being right-handed, native Norwegian speaker, above the age of 60, no diagnosis of orthopaedic, motor or other co-morbidities likely to impact gait and cut-off criteria on MMSE > 27 to assure normal cognitive status (Petersen et al., 1999). Exclusion criteria were having a diagnosis of pathology that directly affects the musculoskeletal system, recent surgery, acute

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