Auditory Navigation in Bilateral Hearing Aid Users

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Introduction

Falls are serious events that have lead to 2.5 million nonfatal outcomes and 21,700 fatal outcomes per year in the United States[1]. Balance has long been considered the result of inputs provided through visual, vestibular, and proprioceptive systems[2]. Recent research has suggested a relationship between hearing loss and increased risk of falls in the elderly[3]. The role of hearing loss in falls is complicated by coexisting reduction in cognitive capacity, secondary vestibular dysfunction, and a loss of spatial perception leading to decrease three-dimensional awareness.

This study examined the ability of an external sound source to improve walking by correcting for veering. In a population continually affected by hearing loss, bilateral hearing aid (BLHA) users were examined to give insights as to whether the benefits of hearing aids extend to improving locomotion and three-dimensional awareness.

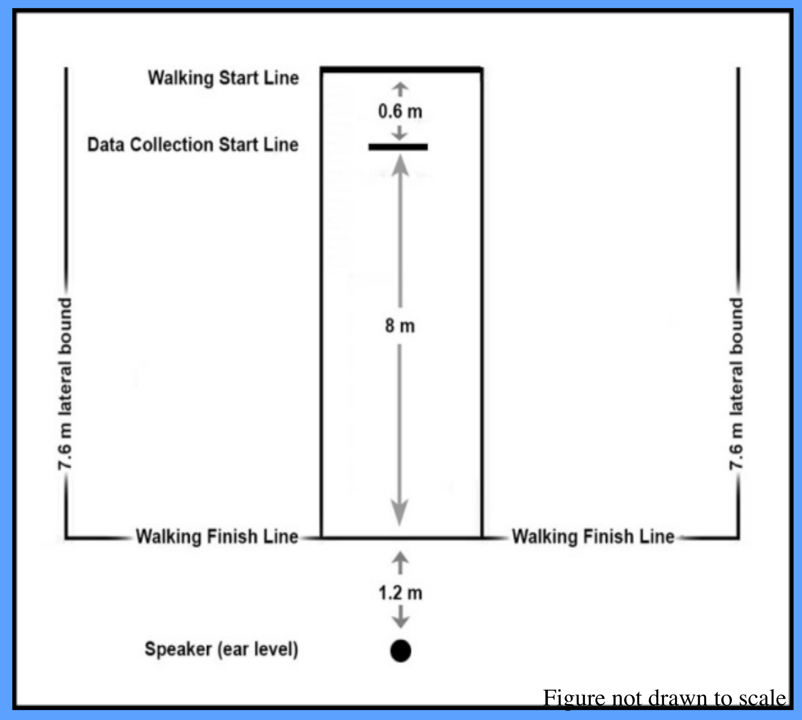
Methods

Young, healthy adults (n=11) with no reported co-morbidities, vestibular impairments, or clinical hearing loss were selected as control population. Bilateral hearing aid users (n=6) were screened to have 3 or more months of hearing aids, aided thresholds of 25dB or worse in each ear, and could ambulate without assistance.

Participants were blindfolded and instructed to walk 8m towards a speaker to the best of their abilities at their preferred paces, see Figure 1. The gait patterns included a normal walk and tandem walk. Subjects subjectively rated their abilities to balance before and after the experiment.

Sound conditions included a broadband white-noise (1-4 kHz, 65dB) speaker located 9.6m from the start location. Over-ear headphones emitted broadband white-noise from a subjective dB level related to standing 1.2m from the speaker. For no sound conditions, the sound speaker was shut off and control subjects wore earplugs and over-ear muffs to stimulate -70dB hearing loss. During the trials in the bilateral hearing aid population, subjects were presented with continuous speaker stimuli and the sound variables included bilaterally aided, unilaterally aided, and unaided hearing.

FIGURE 1: Overview of walking track to measure displacement from central line at the walking finish line



Results

Figure 2: Individual Results from Healthy Participants

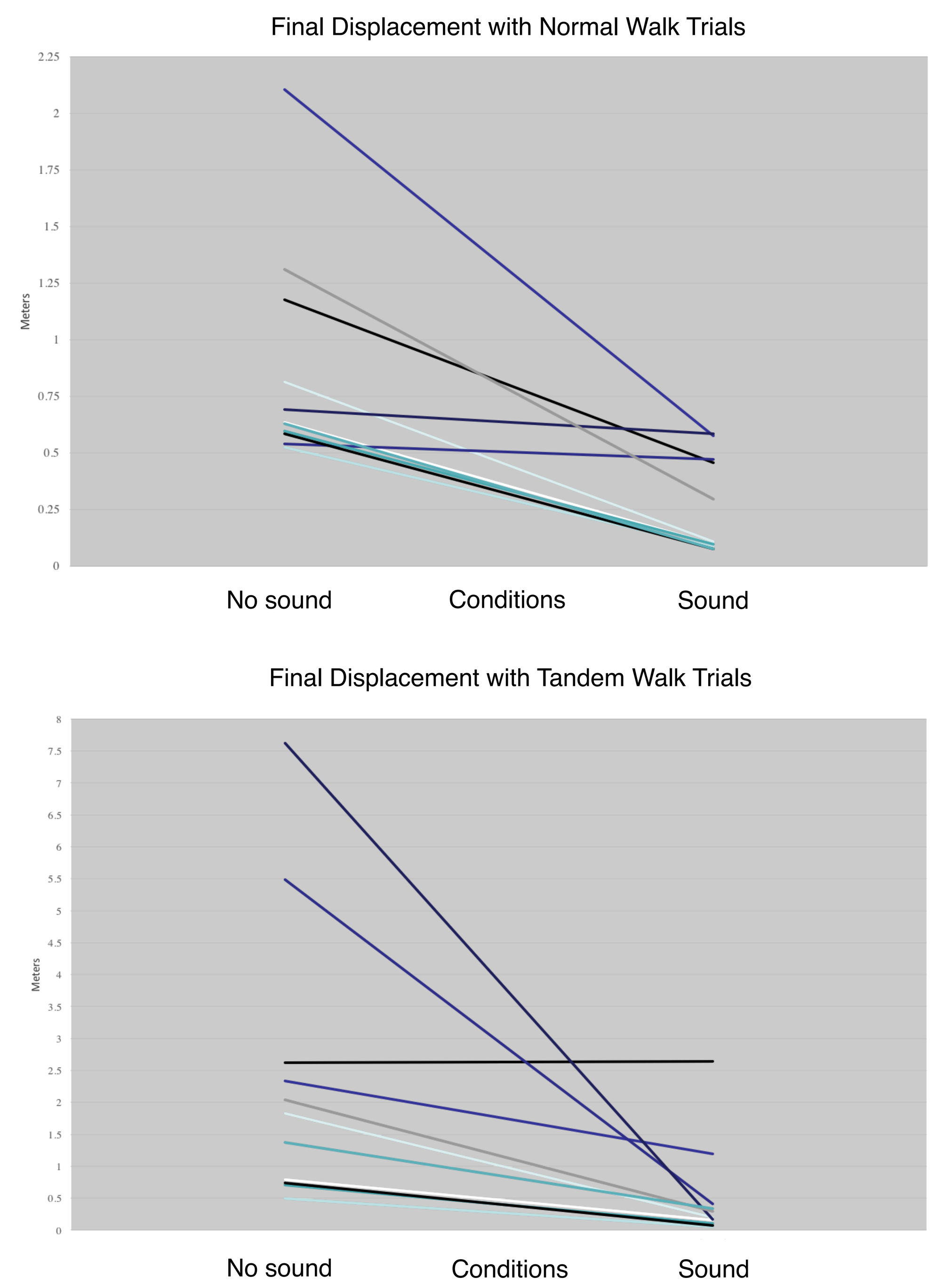


Figure 3:Average of distance from final speaker in control subjects

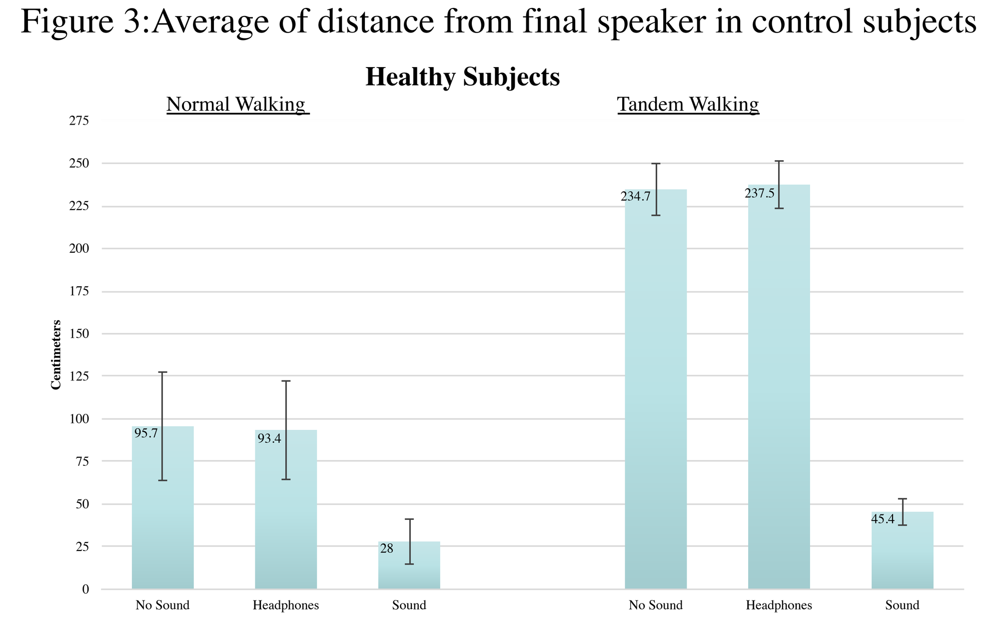


Figure 4: Individual Results from Bilateral Hearing Aid Users

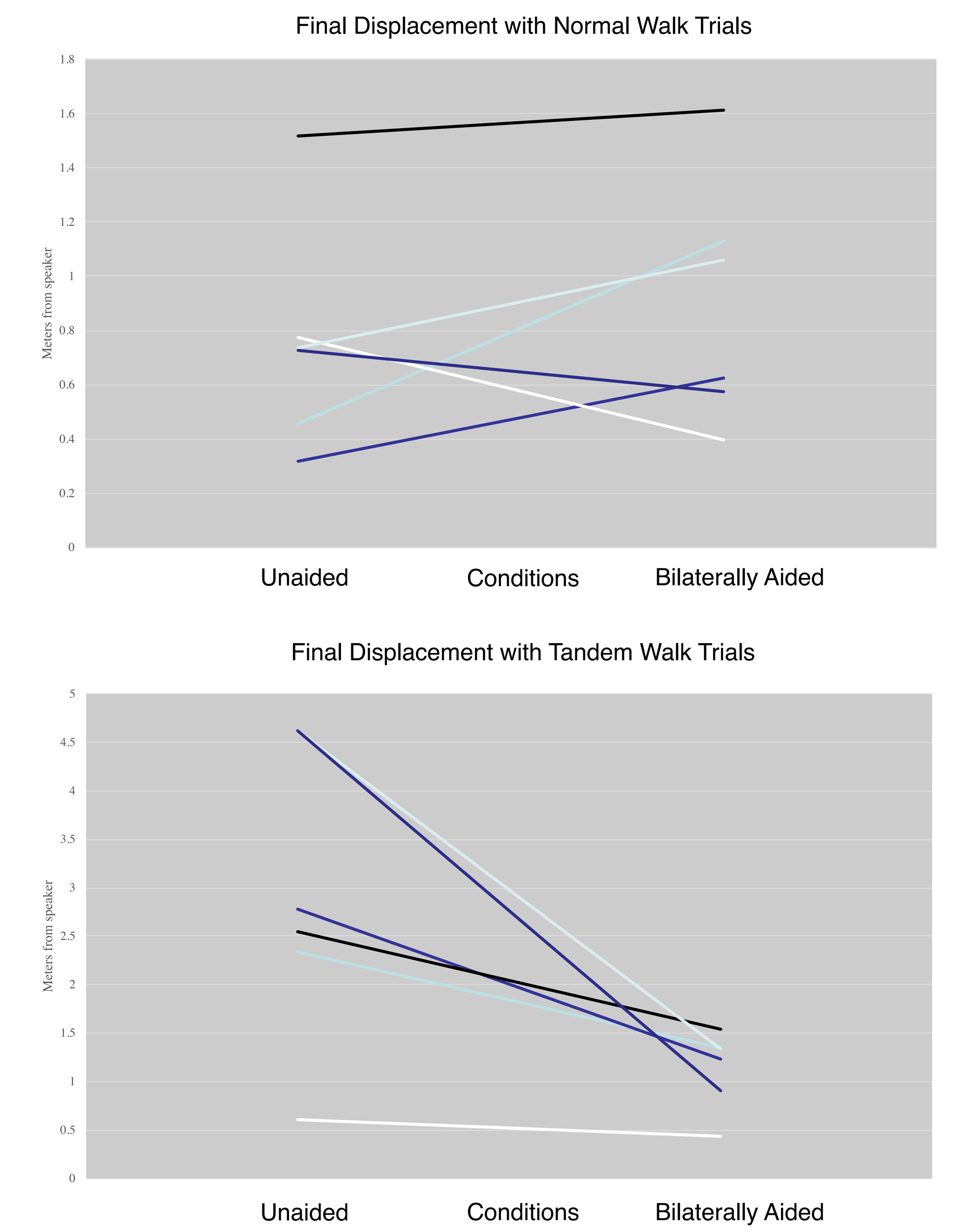


Figure 5: Average of distance from final speaker in BLHA subjects

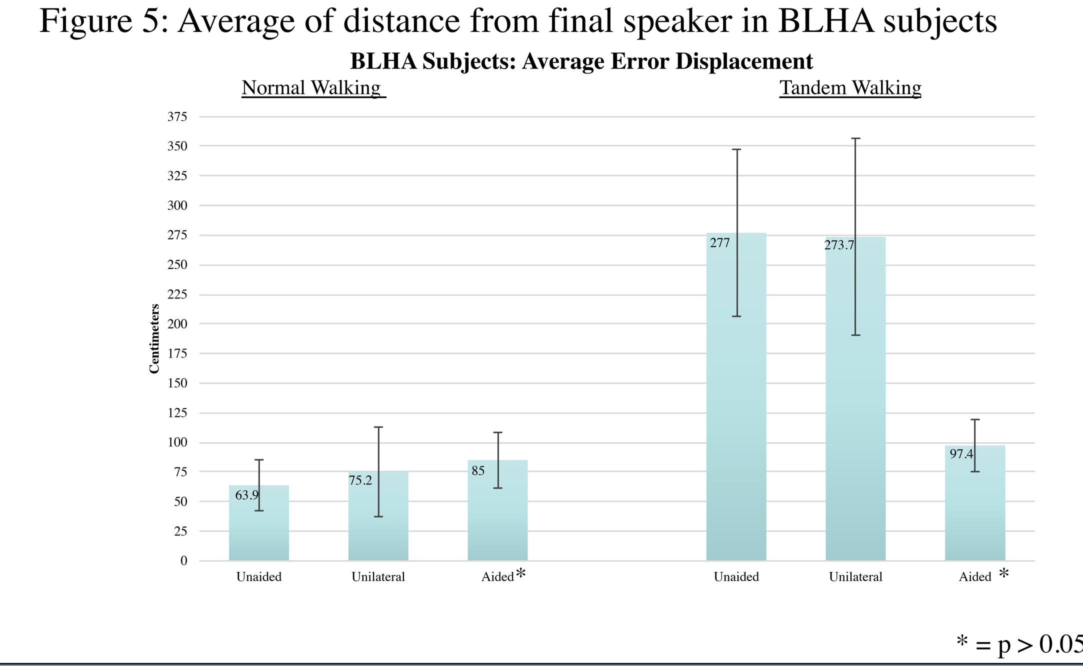


Table 1: Subjective Reports of Balance

Is Balance better with Sound, No Sound, or there is No Difference?						
Healthy Subjects	Before	After		BLHA Subjects	Before	After
With	5	7		Aided	0	0
Without	0	1		Unaided	1	1
No Difference	6	3		No Difference	5	5

11 young, healthy adults, ages 20-30 (mean 25.8) and 6 bilateral hearing aid users, ages 33-69 (mean: 55.6) were selected based on criteria in methods.

The healthy population benefited from silence to sound conditions by decreasing veering from 0.96m to 0.28m, respectively, ANOVA analysis $F(2,63)=7.507$, $p=0.0012$ between groups. A decrease in path detour from 2.35m to 0.45m was observed during tandem walking exercises in healthy subjects, ANOVA analysis [$F(2,63)=5.449$, $p=0.0066$] between groups.

BLHA users showed no significant difference for localization accuracy while walking normally during aided, 0.85m, and unaided, 0.64m, ANOVA analysis [$F(2,16)=0.16$, $p=0.85$]. The tandem walking showed a reduction in veering from unaided, 2.8m, to aided, 0.97m, with an ANOVA Analysis [$F(2,27)=3.12$, $p=0.06$].

Conclusion

Healthy individuals subjectively reported an increase in ability to retain balance while sound cues are available. The objective data shows a significant decrease ($p<.005$) in veering from no sound to the a loud-speaker condition. As predicted, headphones lack of spatial cues led to a similar result to no sound conditions. Healthy subjects are able to utilize sound to navigate during transient low-light conditions under several gait conditions.

BLHA subjects reported no difference in their ability to balance between unaided and aided conditions with one subject reporting improvement in balance without sound. Objective measurements showed no significant difference in normal walking conditions which are ultimately attributed to a small sample size, higher gait velocity lending to automated control, and more experience walking without sound[4,5]. Additionally, co-morbidities in this population may be masking the potential benefits of sound alone. Longer longitudinal studies are needed to examine the role of audition in improving balance and navigation in the BLHA population.

Different walking conditions resulted in large differences in ability to maintain a straight line path. Both populations veered greater distances during heel-to-toe tandem walking conditions throughout all sound conditions. This error is widely attributed to increased number of gait cycles, slower walking speeds, and natural path integration deficits[6].

In this study, spatial awareness using sound is responsible for the reduction in veering associated with imbalance. Veering is a sign of imbalance and increases the risk of falling as seen in those with vestibular loss[7]. This study suggests that an elderly bilateral hearing aid population may not benefit from hearing aid use during transient low-light conditions, such as getting up to use the restroom, yet more evidence is needed to support this. Additionally, sound speakers can be used to benefit populations outside the blind under certain conditions.

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References

1. Web-based Injury Statistics Query and Reporting System (WISQARS) [database online]. Atlanta, GA: Centers of Disease control and Prevention, National Center for Injury Prevention and control: 2015. Updated July 13, 2015. httt://www.cdc.gov/injury/wisqars/.
2. Nashner LM. "Practical biomechanics and physiology of balance." Handbook of Balance Function Testing. St. Louis: *Mosby Year Book*, 261–279. (1993)
3. Jiam, N. T.-L., Li, C., & Agrawal, Y. "Hearing loss and falls: A systematic review and meta-analysis." *The Laryngoscope*, 1–10. (2016). http://doi.org/10.1002/lary.2592
4. Al., U. A. "Preferred step frequency minimizes veering during natural human walking." *Neuroscience Letters*, *vol: 505*(3), 291–293. (2011) http://doi.org/10.1016/j.neulet.2011.10.057
5. M. Wuehr, R. Schniepp, C. Pradhan. "Differential effects of absent visual feedback control on gait variability during different locomotion speeds." *Exp Brain Res*, vol: 224(2),287-294. (2013). doi:10.1007/s00221-012-3310-6
6. Cohen, H. S., & Sangi-Haghpeykar, H. "Walking speed and vestibular disorders in a path integration task." *Gait and Posture*, *33*(2), 211–213. (2011).http://doi.org/10.1016/j.gaitpost.2010.11.007
7. Courtine, Grégoire, and Marco Schieppati. "Human Walking along a Curved Path. I. Body Trajectory, Segment Orientation and the Effect of Vision." *European Journal of Neuroscience* 18.1 (2003): 177–190. Web.