EFFECTS OF HEAD-WORN DISPLAY USE ON OBSTACLE CROSSING PERFORMANCE IN A SIMULATED OCCUPATIONAL TASK

Sunwook Kim, Sophia Ulman, and Maury A. Nussbaum

Industrial & Systems Engineering, Virginia Tech, Blacksburg, VA, USA
Email: sunwook@vt.edu

INTRODUCTION

Slips, trips, and falls (STFs) continue to be a major cause of occupational injuries and fatalities. For example, STFs accounted for 16.5% of fatal occupational injuries and 27% of lost workday cases in 2015 [1]. The occupational application of smart glasses, or head-worn displays (HWDs), has been explored in diverse applications [2], and may lead to potential benefits since a HWD can project diverse, real-time information in front of one (monocular) or both eyes (binocular) of a user. Though broad evidence supports that an increase in attentional demand and/or cognitive distraction can reduce gait performance [3], there is limited evidence that has been reported regarding the potential impacts of HWD use on gait performance, particularly with respect to obstacle crossing (OC). This study thus assessed the effects of different HWD technologies and information presentation types on OC performance. Two commercially-available HWDs were used, representing binocular (Epson Moverio BT-200) and monocular (Vuzix M100) technologies. Based on earlier work, we hypothesized that the use of a HWD would deteriorate OC performance.

METHODS

This study involved 12 gender-balanced participants, with self-reported normal or corrected-to-normal vision (contact lenses only), and no recent or current musculoskeletal disorders or injuries. The mean (SD) age, stature, and body mass were 25.3 (6.0) yrs, 177.2 (6.2) cm, and 74.2 (8.3) kg, respectively for males; and 30.2 (14.3) yrs, 164.2 (4.8) cm, and 55.8 (5.4) kg, respectively, for females. Testing was performed with IRB approval, and informed consent was obtained.

A 3×2×2 repeated measures design was used to assess the effects of *Information mode* (paper list, binocular HWD, monocular HWD), *Information type* (text- vs. graphic-based instructions for a simulated assembly task), and *Gender* on OC performance. Participants were provided with consistent shoe types and asked to walk on a linear gait track at a "purposeful" walking speed [4]. After familiarization, participants completed three gait trials to establish a baseline (i.e., no info. mode) and then all the experimental conditions. The order of experimental conditions was counter-balanced.

Triaxial ground reaction forces (GRFs) were collected from two force plates (AMTI, OR-6). Gait kinematics were collected using a 10-camera motion capture system (Vicon, Vero), using passive reflective markers placed on select anatomical landmarks. Eight markers were also placed around the shoe outsole [5], and four markers were placed on each corner of the obstacle (made of dense foam, see Figure 1).

Minimum foot clearance (MFC) and peak required coefficient-of-friction (RCOF) between the shoe and floor surface were used to assess OC performance. RCOF was obtained from each force plate as: $\sqrt{F_X^2 + F_Y^2}/|F_Z|$ where F_X, F_Y, and F_Z are the shear and normal GRFs, respectively. Peak RCOF was then extracted [6]. MFC was defined as the lowest location among the reconstructed shoe outsole markers near the mid-swing phase of gait, and was calculated separately for the lead and trail feet over the obstacle [5]. Foot placement location around the obstacle was obtained [7], including the trail horizontal toe and the lead horizontal heel distances (Fig. 1). Obstacle crossing speed (OCS) was estimated as the mean velocity of four pelvis markers during the obstacle crossing step. Mixed-factor analyses of variance were performed on OC

performance measures to assess the effects of gender, *Info. mode,* and *Info. Type*, while including the corresponding baseline measure as a covariate.

Figure 1: OC performance measures obtained.

RESULTS AND DISCUSSION

Participants exhibited significant changes in some OC performance measures (i.e., RCOF2 or lead heel distance) relative to baseline measures. Additionally, MFC_{LEAD} was significantly affected by a main effect of *Info. Mode*, and an *Info. Mode × Info. Type × gender* interaction effect (Fig. 2). MFC_{LEAD} was generally comparable between *Info. type* conditions with one exception, and larger for females vs. males.
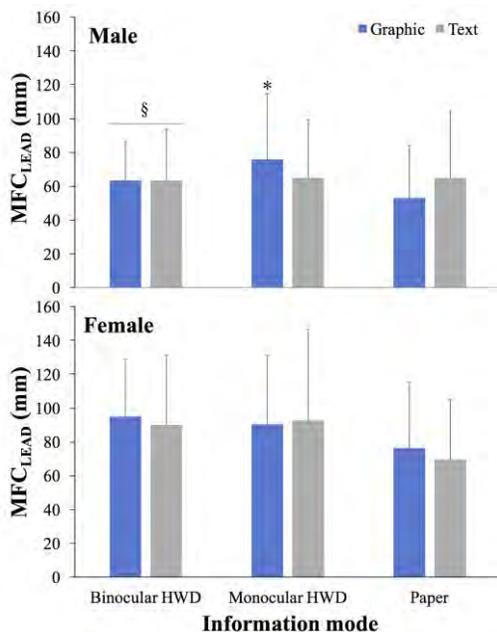

Figure 2: Three-way interaction effect of *Info. mode*, *Info. type*, and *gender* on MFC_{LEAD}. Note: * and § indicate significant differences between *Info. type* conditions and between genders, respectively.

When attentional demand increases, reducing the OCS may have been a strategy to maintain postural stability (i.e., cautious gait). Use of a HWD resulted in a slight decrease (~4%) in OCS compared to the baseline, but such a decrease was not apparent for the paper list condition. This may suggest that visuospatial attentional demands were higher with HWD use (vs. the paper list), given that walking/obstacle crossing requires visual and visuospatial information to control limb trajectories [8]. Also, HWD use seemed to cause more conservative obstacle crossing behaviors, which may be gender specific. Common strategies to reduce trip risks include decreasing OCS, increasing MFC_{LEAD}, and/or increasing the trail toe distance while reducing the lead heel distance [3]. Here, when using the monocular HWD or paper list, males increased the trail toe distance while reducing the lead heel distance. When using a HWD, females exhibited increased MFC_{LEAD} values.

In summary, we examined the effects of HWD use on OC performance. Our results demonstrate that the use of HWDs may cause the adoption of specific gait strategies. Yet, given potential study limitations (i.e., young participants, rather optimal walking condition), future efforts are needed to understand more completely how HWD use might affect gait performance of diverse working populations, for longer-term use, and under suboptimal or more challenging walking conditions.

REFERENCES

1. Bureau of Labor Statistics. *bls.gov*, Washington, DC, 2016.
2. Henderson S & Feiner S. *IEEE Trans. Vis. Comput. Graphics,* **17**, 1355-68, 2011.
3. Harley C, et al. *Gait & Posture,* **29**, 428-32, 2009.
4. Beringer DN, et al. *PLoS ONE,* **9**, e96525, 2014.
5. Startzell JK & Cavanagh PR. *Hum Mov Sci,* **18**, 603-11, 1999.
6. Chang WR, et al. *Hum Factors*, **53**, 461-73, 2011.
7. Chen HC, et al. *J Gerontol,* **46**, 196-203, 1991.
8. Patla AE, et al. *J Mot Behav,* **28**, 35-47, 2010.

ACKNOWLEDGMENTS

ABSTRACTS