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Effect of Cane Length on Drop-off Detection Performance

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Although individuals who are blind have used a stick or a cane for their independent travel since the early years of human history, designs for modern long canes did not appear until World War II, when the systematic long cane techniques were developed by Hoover (1962). Ergonomic factors, such as the length of the cane, may affect how well a cane user can detect the presence of obstacles and changes in surface elevation, including drop-offs. Reliable drop-off detection with a long cane, an essential component of surface preview (Blasch, La Grow, & De l'Aune, 1996), is critical for the safety of travelers who are blind who use canes, since missing drop-offs or other changes in elevation in the walking surface may cause them to fall or accidentally stumble into the collision path of approaching vehicles.

Kim, Wall Emerson, and Curtis (2009) found that cane users were able to detect drop-offs more reliably when they used the constant contact technique than when they used the two-point touch technique. The characteristics of cane users may also influence the users' performance in detecting drop-offs. In Kim, Wall Emerson, and Curtis's (2010a) study, younger users were able to detect drop-offs more reliably than were older cane users. Cane users who lost their vision early in life also detected drop-offs more reliably than did those who lost their vision later (Kim et al., 2010a). In addition, those who had regularly used a cane for at least two years performed better than did those who were less experienced (Kim, Wall Emerson, & Curtis, 2010c).

Detecting drop-offs may also be influenced by ergonomic factors, such as the type of cane tip (Kim, Wall Emerson, & Curtis, 2010b) and length of the cane (Rodgers & Wall Emerson, 2005). How the length of a cane may affect the detection of drop-offs is of particular interest because there appear to be different opinions on this matter among cane users. According to the traditional method (called the "sternum method"), a proper cane length is defined as the vertical distance from the ground to 2 inches above the xiphoid process (La Grow & Weessies, 1994). In a study conducted with 10 adult cane users who were visually impaired (that is, those who were blind or had low vision), Rodgers and Wall Emerson (2005) reported that the use of a standard-length cane, measured by the sternum method, allowed the users to detect drop-offs significantly better than with the canes that were either 5%–15% shorter or 10%–20% longer than the standard length. However, some cane travelers have advocated for a cane that is substantially longer than the standard length.

For example, Willoughby and Monthei (1998) suggested that although a cane user's stride, walking speed, and reflexes should be considered, a cane that reaches only to the sternum is not long enough to ensure safety for an average cane user. In addition, Kish (2009) suggested, on the basis of personal anecdotal experience, that children up to age 6 should use canes that are as long as their height and that adult travelers need to use canes that are about chin high. Given this controversy, we investigated whether the length of the cane affects the detection of drop-offs. We also examined whether there is an interaction between the length of a cane and the depth of a drop-off.

Method

A repeated-measures design with block randomization was used for the study. We recruited 15 sighted students (13 female and 2 male) aged 22 to 55 (median age = 34) from the orientation and mobility (O&M) program at Western Michigan University who were familiar with both the two-point touch and constant contact techniques. These students had received 1 month to 4 months (median = 1.4 months) of cane training.

A 32-foot-long walkway with six carpeted plywood platforms (8 feet long, 4 feet wide, and 8 inches high) was used for the study. We placed two plywood boards (2 feet long and 4 feet wide) on top of braced rectangular frames (2 feet long, 4 feet wide, and 2 inches high) against the lengthwise end of the walkway to change the depth of the drop-off from trial to trial. The participants used identical canes (the Ambutech UltraLite Graphite Rigid Cane) of different lengths with identical cane tips (the Ambutech MT4080 High Mileage Tip). Further details of the apparatus and research procedure are presented in Kim et al. (2009).

Procedure

On arriving at the study site, each participant signed the informed consent form approved by Western Michigan University's Human Subjects Institutional Review Board. Sleep shades and a full-size headphone set (RadioShack Full-Size Stereo Headphone 33-1225) connected to an MP3 player (Apple iPod 5th Generation) were worn by each participant during all the trials. We varied the starting points randomly (14 feet to 30 feet from the drop-off) from trial to trial to prevent the participants from estimating the distance to the drop-off. On receiving a signal from the experimenter, a participant walked toward the drop-off using either the standard-length cane or the extended-length cane (10 inches longer than the standard length) according to the randomized schedule of the trials. The standard length was defined as the vertical distance from the ground to 2 inches above the cane user's xiphoid process, following the sternum method outlined by La Grow and Weessies (1994).

Each participant completed eight trials for each of four drop-off depths (1 inch, 3 inches, 5 inches, and 7 inches) using each cane length (the standard length and the extended length) for a total of 64 trials. We recorded a trial as a miss if the participant fell off the drop-off or would have fallen off the drop-off if the experimenter did not intervene; interrater reliability was 96%.

Variables

We used the 50% absolute drop-off detection threshold and drop-off detection rates to measure the participants' detection of drop-offs (the dependent variables). We calculated the 50% absolute drop-off detection threshold for each cane-length condition using the psychometric function outlined in Gescheider (1997). The overall drop-off detection rate was calculated by dividing the total number of detections by the total number of trials. The cane length and drop-off depth were the independent variables.

Analysis

After we completed the descriptive statistical procedures, we used a two-way repeated-measures analysis of variance (ANOVA) and within-subjects *t* tests to answer our research questions. In the case of the violation of the sphericity assumption, we made adjustments to the ANOVA results using the Greenhouse-Geisser (1959) degree of freedom correction. We used a significance level of .05 for all the statistical tests (two tailed). The statistical power of the *F* tests and *t* tests was .82 or higher when a large effect size ($f = .4$ or $d = .8$) was assumed (Cohen, 1988; Erdfelder, Faul, & Buchner, 1996). All the statistical analyses, except for the power analyses (G*Power version 3.0.10), were conducted with SPSS version 16.0.

Results

The 50% drop-off-detection threshold with the standard-length cane ($M = 1.62$ inches, $SD = .83$ inches) was not statistically significantly different from that with the extended-length cane ($M = 1.98$ inches, $SD = 1.27$ inches), $t(14) = -1.399$, $p = .184$ (see Figure 1). The overall drop-off detection rate with the standard-length cane ($M = 78.3\%$, $SD = 11.0\%$) was not statistically significantly different from that with the extended-length cane, either ($M = 75.2\%$, $SD = 16.2\%$), $F(1, 14) = .868$, $p = .367$.

The participants' drop-off detection performance improved as the depth of the drop-off increased, $F(1.94, 27.22) = 95.028$, $p < .001$, albeit with a declining rate (see Figure 2). However, there was no statistically significant interaction between the cane length and drop-off depth, $F(1.52, 21.29) = .271$, $p = .705$.

Discussion

Interpretation and practical implications

We found no significant difference in the participants' detection of drop-offs between the standard-length and the extended-length canes. One possible explanation may be that the difference in the cane lengths used in the study (10 inches) was not large enough to effect a difference in the participants' performance in detecting drop-offs between the two conditions. It is possible that a larger difference in the length of canes may produce a significant difference in the detection of drop-offs. However, it is also possible that the length of a cane has a limited effect on participants' performance in detecting drop-offs when the constant contact technique is used, but a more noticeable effect when the two-point touch technique is used. This may be why Rodgers and Wall Emerson (2005) found the

standard length (sternum method) to be superior to the 10%–20% longer lengths for detecting drop-offs in their study, in which the participants used the two-point touch technique, whereas we found no such difference in this study, in which the participants tried to detect the drop-offs using the constant contact technique.

The 50% drop-off detection threshold difference of .4 inches (1.6 inches versus 2.0 inches) between the standard- and extended-length conditions does not appear to be a meaningful difference for cane users. The difference in the overall drop-off detection rate of 3.1% (78.3% versus 75.2%) does not seem to be practically significant for most cane users either.

Limitations and recommendations

One limitation of the study is related to the use of sighted O&M students, rather than cane users who are blind, which may limit the generalizability of the findings for travelers who are blind. However, the drop-off detection threshold of cane users who were blind who participated in the previous studies that used the identical protocol ($M = 1.55$ inches, $SD = .74$ inches, median age = 33, median cane-use experience = 2.2 months, $n = 6$) was similar to that of the sighted individuals who participated in this study ($M = 1.62$ inches, $SD = .82$ inches, median age = 34, median cane-use experience = 1.4 months, $n = 15$); for this comparison, two groups were equalized with respect to age and cane-use experience, which was found to be significantly related to the detection of drop-offs (Kim et al., 2010a, 2010c). The overall drop-off detection rate of the cane users who were blind in the previous studies ($M = 78.6\%$, $SD = 10.0\%$, $n = 6$) was also similar to that of the sighted participants of this study ($M = 78.3\%$, $SD = 11.0\%$). Another limitation was related to the use of only inexperienced cane users. None of the participants had more than 4 months of cane-use experience, which may limit the generalizability of the findings for experienced cane users.

A systematic investigation of interactions among cane length, type of cane technique, and drop-off depth may be needed to determine whether such interactions are present. The inclusion of experienced cane users may also be needed to enhance the generalizability of the findings. In addition, conducting an experiment in a more ecologically valid environment, such as an actual sidewalk with surface irregularities, may be necessary to demonstrate the practical applicability of the findings. Furthermore, investigation of how other ergonomic factors, including weight and flexibility of the cane shaft, affect the detection of drop-offs may be useful.

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Figure 1.

50% absolute drop-off-detection threshold. Error bars indicate 95% confidence intervals.

Figure 2.

Drop-off-detection rates by cane length. The p value for each drop-off depth indicates the result of the corresponding pairwise comparison between the standard-length and extended-length conditions.