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Interaction Effects of the Amount of Practice, Preferred Cane Technique, and Type of Cane Technique Used on Drop-off Detection Performance

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Abstract

This study examined the interaction effects of the amount of practice and the cane technique used in drop-off detection with a sample of 32 adults who were blind. The advantage of the constant contact technique over the two-point touch technique was significantly greater for the less experienced cane users than for the more experienced ones.

The two-point touch and constant contact techniques are the most widely used long cane techniques by travelers who are blind (LaGrow & Weessies, 1994). Regardless of which cane technique is used, it is critical for a cane user who is blind to detect drop-offs reliably; missing drop-offs or other changes in the elevation of walking surfaces may cause falls or accidental stumbling into the collision path of an oncoming vehicle (Uslan & Schriebman, 1980).

The type of cane technique used may influence a cane user's ability to detect drop-offs, thus affecting the safety of the user's travel. In a preliminary study (Kim, Wall Emerson, & Curtis, 2009), the constant contact technique (overall detection rate of 82.7%) was found to have an advantage over the two-point touch technique (overall detection rate of 62.5%) in detecting drop-offs. However, the sample of 15 cane users in that study included only 2 who used the two-point touch technique as their preferred cane technique, which limited the generalizability of the findings.

Training may also affect a cane user's detection of drop-offs, since it can generally improve human perceptual abilities (Platt & Racine, 1985; Recanzone, Merzenich, & Jenkins, 1992; Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000). In particular, a few studies have shown that proprioceptive or kinesthetic and vibrotactile perceptual abilities, which appear to be involved in detecting drop-offs with the long cane, can be improved by practice (Diespecker, 1970; Fleischman & Rich, 1963; Graydon & Townsend, 1984; Sims & Morton, 1998). For example, after 20 instructional sessions (5 blindfolded trials in each session), 10 adolescent girls showed a significantly improved accuracy of short serves in badminton (Graydon & Townsend, 1984), while 50 undergraduate students demonstrated a significantly higher accuracy in discriminating the intensity and duration of vibrotactile stimuli applied to one of the five locations in their arms (fingertips, palms, wrists, forearms,

and upper arms) after a single session of 10 trials (Diespecker, 1970). Our preliminary study (Kim et al., 2009) also found a positive correlation between the amount of practice with a cane technique and the detection of drop-offs. However, it was a simple description of the data on the sample, from which no inference to the corresponding population was made.

Enhancing vibrotactile sensitivity does not appear to require extensive practice (Diespecker, 1970; Fucci, McCaffrey, Curtis, & Blackmon, 1974; Godde, Spengler, & Dinse, 1996; Maeda & Griffin, 1995; Schenkman, 1986), although the results seem mixed with respect to the amount of practice needed to improve proprioceptive and kinesthetic sensitivities (Crilly, Willems, Trenholm, Hayes, & Delaquerrere-Richardson, 1989; Graydon & Townsend, 1984; Islam et al., 2004; Sims & Morton, 1998; Wolf, Barnhart, Ellison, & Coogler, 1997). In addition, some orientation and mobility (O&M) specialists have stated that it takes longer for many cane users to become competent in detecting drop-offs with the two-point touch technique than with the constant contact technique (R. O. LaDuke, personal communication, February 4, 2009; M. J. Weessies, personal communication, February 4, 2009). However, no prior published studies have experimentally examined the interaction between the amount of practice and the cane technique used in detecting drop-offs.

One of the primary purposes of the study presented here was to determine whether the constant contact technique's advantage over the two-point touch technique in detecting drop-offs (Kim et al., 2009) could be supported when a more balanced sample—particularly with respect to participants' preferred cane technique—was used. Another key purpose was to examine how practice and the preferred cane technique affect the detection of drop-offs as they interact with the type of cane technique that is used.

Method

Study design and recruitment criteria

A mixed-measures design with block randomization was used for the study, in which the participants detected the drop-offs using either the two-point touch or the constant contact technique. Recruitment criteria included legal blindness with no other disability, familiarity with both the two-point touch and the constant contact techniques, and a minimum of one month of training with the long cane.

A total of 32 cane users were recruited for the study; 17 additional cane users were recruited in 2009 to balance the original cohort of 15 participants who participated in 2008 (Kim et al., 2009) with respect to the preferred cane technique, age, and amount of practice. Identical recruitment criteria and an identical experimental protocol allowed us to combine the data from the preliminary study of 15 participants with those from the latest 17 participants for the analysis.

Apparatus

Six carpeted plywood platforms (8 feet long, 4 feet wide, and 8 inches high), supported by 2 × 4 braces, formed a 32-foot-long walkway (see Figure 1). Two plywood boards (2 feet long and 4 feet wide) placed on top of braced rectangular frames (2 feet long, 4 feet wide, and 2 inches high) were used to change the depth of the drop-off at the end of the walkway from trial to trial.

The participants used identical canes of different lengths (Ambutech Ultra-Lite Graphite Rigid Cane) with identical cane tips (Ambutech MT4080 High Mileage Tip). The length of a participant's cane was assigned on the basis of the participant's height; the vertical distance from the ground to 2 inches above the participant's xiphoid process was used to select the

appropriate cane length for the participant (LaGrow & Weessies, 1994). Further details on the apparatus and research procedure are presented in Kim et al. (2009).

Research procedure

Each participant signed the informed consent form approved by Western Michigan University's Human Subjects Institutional Review Board before participating in the study. 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.

To keep the participants from estimating the distance to the drop-off, we randomly selected starting points (14 feet to 30 feet from the drop-off) for each trial. Upon receiving a signal from the experimenter, a participant walked toward the drop-off using either the two-point touch technique or the constant contact technique, according to the randomized schedule of trials.

Eight trials for each of four drop-off depths (1 inch, 3 inches, 5 inches, and 7 inches) using each technique (the two-point touch and the constant contact) resulted in a total of 64 trials per participant. If the participant fell off the drop-off or would have fallen off the drop-off if the experimenter had not intervened, the trial was regarded as a miss. Interrater reliability for detecting drop-offs was 98% in the preliminary study (Kim et al., 2009).

Variables

The absolute drop-off detection threshold (50%) and drop-off detection rates were used to measure the participants' performance in detecting drop-offs (dependent variables). We calculated the 50% absolute drop-off detection threshold for each technique 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 large drop-off detection rate was computed in a similar manner, but only with the 5- and 7-inch drop-off detection rates combined. The type of cane technique that was used in the drop-off detection trial (within group), years of cane use (between groups), and preferred cane technique (between groups) were the independent variables.

Analysis

After we completed descriptive statistical procedures, we used a two-way mixed-measures analysis of variance (ANOVA) to test the hypotheses; we did not examine a three-way interaction because of limited interpretability and practical benefits. In the presence of significant interactions, we examined simple effects, rather than main effects (Keppel, 1991). We used the Welch (1951) procedure when the homogeneity of variance assumption was violated.

We tested the following two specific interactions: (1) years of cane use $\times$ the type of cane technique used in drop-off detection and (2) the preferred cane technique $\times$ the type of cane technique used in drop-off detection. The interaction between the two between-groups variables—years of cane use $\times$ preferred cane technique—was examined purely descriptively, given the limited statistical power and imbalanced number of participants in subcategories.

A significance level of .05 was used for all statistical tests (two tailed) in the study. The statistical powers of tests of the main effect, simple effect, and interaction effect were .54 or higher when a large effect size ($f = .4$) was assumed (Cohen, 1988; Erdfelder, Faul, &

Buchner, 1996). All statistical analyses, except for power analyses (G*Power version 3.0.10), were conducted with SPSS version 16.0.2.

Results

Demographic characteristics of the participants

Of the 32 participants, 18 were men and 14 were women aged 20 to 75 (median age = 37). The participants' visual acuities ranged from no light perception to 20/200. The etiologies of the participants' visual impairments included retinitis pigmentosa ($n = 5$), glaucoma ($n = 3$), retinopathy of prematurity ($n = 3$), diabetic retinopathy ($n = 3$), retinal detachment ($n = 2$), microphthalmia ($n = 2$), and others ($n = 14$). All the participants used the long cane as their primary mobility aid; 11 participants used the two-point touch technique more frequently (60%–95% of the time, median = 75%, median age = 48), and the remainder used the constant contact technique more often (60%–95% of the time, median = 85%, median age = 30). The duration of cane use of the experienced cane users ($n = 24$) was at least 2 years and spanned up to 42 years (median = 14 years, median age = 36), while that of the inexperienced group ($n = 8$) ranged from 1 month to 13 months (median = 2 months, median age = 41).

Main effects

There was no statistically significant interaction between the preferred cane technique and the type of cane technique used in the drop-off detection trial, $F(1, 30) = .052$, $p = .820$. Therefore, the main effects of these two factors were examined (Keppel, 1991). As can be seen in Table 1, the drop-off detection threshold of the constant contact technique ($M = 1.65$ inches, $SD = .93$ inches) was statistically significantly smaller (more sensitive) than that of the two-point touch technique ($M = 2.91$ inches, $SD = 1.14$ inches), $F(1, 30) = 68.240$, $p < .001$. The overall drop-off detection rate of the constant contact technique ($M = 79.7\%$, $SD = 14.1\%$) was also statistically significantly higher than that of the two-point touch technique ($M = 62.9\%$, $SD = 12.7\%$), $F(1, 30) = 64.079$, $p < .001$. Even for large drop-offs (5 inches or 7 inches), which could pose a serious risk of falling if missed, the drop-off detection rate with the constant contact technique ($M = 99.2\%$, $SD = 2.1\%$) was statistically significantly higher than that with the two-point touch technique ($M = 93.4\%$, $SD = 12.2\%$), $F(1, 30) = 6.216$, $p = .018$. There was no statistically significant order effect of the cane technique on the drop-off detection threshold, $F(1, 30) = .001$, $p = .982$; the overall drop-off detection rate, $F(1, 30) = .160$, $p = .692$; or the drop-off detection rate for large dropoffs, $F(1, 30) = .242$, $p = .627$.

The drop-off detection threshold of the participants whose preferred cane technique was the two-point touch ($M = 2.31$ inches, $SD = .97$ inches) was not statistically significantly different from that of those whose preferred cane technique was the constant contact ($M = 2.26$ inches, $SD = .94$ inches), $F(1, 30) = .021$, $p = .886$ (see Table 1). Similarly, the overall drop-off detection rate of the participants whose preferred cane technique was the two-point touch ($M = 71.6\%$, $SD = 12.7\%$) was not statistically significantly different from that of those whose preferred cane technique was the constant contact ($M = 71.1\%$, $SD = 12.3\%$), $F(1, 30) = .010$, $p = .922$. The detection rate for large drop-offs between the two groups did not differ statistically significantly, either (two-point touch, $M = 97.7\%$, $SD = 4.4\%$; constant contact, $M = 95.5\%$, $SD = 7.6\%$), $F(1, 30) = .776$, $p = .385$.

Given the significant interaction between the years of cane use and the type of cane technique used in detecting dropoffs (see Figure 2)— $F(1, 30) = 20.025$, $p < .001$ —simple effects, rather than the main effects, were examined in the analysis of these two variables (Keppel, 1991). As can be seen in Table 1, for those who had used the cane for fewer than

two years, the threshold of the constant contact technique ($M = 1.40$ inches, $SD = .69$ inches) was statistically significantly smaller than that of the two-point touch technique ($M = 3.64$ inches, $SD = 1.37$ inches), $F(1, 7) = 56.785$, $p < .001$. The advantage of the constant contact technique over the two-point touch technique was found for the more experienced group as well (constant contact, $M = 1.74$ inches, $SD = 1.00$ inches; two-point touch, $M = 2.66$ inches, $SD = .97$ inches, $F(1, 23) = 44.700$, $p < .001$), albeit by a much smaller degree.

Table 1 also shows that the detection rate for the large drop-offs with the constant contact technique ($M = 98.4\%$, $SD = 2.9\%$) was statistically significantly higher than that with the two-point touch technique ($M = 83.6\%$, $SD = 19.2\%$) for those who had used the cane for fewer than two years, $F(1, 7) = 5.863$, $p = .046$. For more experienced cane users, the large drop-off detection rate with the constant contact technique ($M = 99.5\%$, $SD = 1.8\%$) was also statistically significantly higher than that with the two-point touch technique ($M = 96.6\%$, $SD = 6.6\%$), $F(1, 23) = 4.467$, $p = .046$. However, as was the case with the drop-off detection threshold, the difference in the drop-off detection rate between the constant contact technique and the two-point touch technique for the less experienced cane users ($M = 14.8\%$, $SD = 17.3\%$) was much larger than that for the experienced cane users ($M = 2.9\%$, $SD = 6.8\%$).

Discussion

We found that the cane users detected drop-offs significantly more reliably when they used the constant contact technique than when they used the two-point touch technique. We also found that the advantage of the constant contact technique over the two-point touch technique in detecting drop-offs was significantly larger for the less experienced cane users than for the more experienced ones.

Effect of the type of cane technique that was used

The participants detected drop-offs better when they used the constant contact technique than when they used the two-point touch technique, regardless of what their preferred cane technique was. It is particularly important to note that the difference in the participants' performance in detecting drop-offs between the constant contact technique and the two-point touch technique was significant, both statistically and clinically. For example, even for large drop-offs (5 inches or 7 inches), which could pose a serious risk of falling if missed, the participants still missed 1 in 15 drop-offs with the two-point touch technique but fewer than 1 in 100 with the constant contact technique.

One of the possible explanations for the constant contact technique's advantage over the two-point touch technique may be found in the difference in the length of interstimulus intervals. To detect dropoffs using the constant contact technique, a cane user needs to discriminate between the two stimuli that are presented with no (or a marginal in length) interstimulus interval, whereas to detect drop-offs using the two-point touch technique, the user is required to compare the two stimuli with a longer interstimulus interval. That is, the vibrotactile feedback that a cane user receives when using the constant contact technique—sweeping the cane side to side with the cane tip in constant contact with the walking surface—changes little during his or her approach to the drop-off. Then this steady baseline stimulus is instantly followed by increased pressure on the cane-holding hand when the cane tip passes the drop-off edge and lands on the sunken surface. When the two-point touch technique—intermittent tapping on the walking surface—is used, however, the vibrotactile feedback that a cane user receives at the moment the cane tip hits the depressed surface is temporally separated by an interval (between the cane taps) from the vibrotactile stimulus the user received during his or her approach to the drop-off. The related literature supports the advantage of continuous stimuli (or with shorter intervals) over the stimuli separated by

longer intervals in forced-choice discrimination tasks across different sensory modalities, including the proprioceptive or kinesthetic and vibrotactile senses (Gescheider, Bolanowski, Verrillo, Arpajian, & Ryan, 1990; Kaplan, Nixon, Reitz, Rindfleisch, & Tucker, 1985; Wickelgren, 1966).

Effect of the preferred cane technique

We did not find a statistically significant difference in the detection of drop-offs by the participants who used the two-point touch as the preferred cane technique and those who used the constant contact technique. One possible explanation for such a result is that regardless of which technique was used as the cane user's preferred cane technique, the participant may have used the other technique often enough to develop and maintain competence in both techniques. Another possible explanation may be found in the fact that the group who preferred the two-point touch technique was statistically significantly older than the group who preferred the constant contact technique, with median ages of 48 and 30, respectively. Since age appears to have a negative affect on the detection of drop-offs (Kim et al., 2009), the differences of the two groups could have masked a possible effect of the preferred cane technique. Such a masking effect, however, did not seem to be substantial, given the insignificant main effect of the preferred cane technique, $F(1, 18) = 1.998, p = .175$, even in the comparison that was made after the younger participants were trimmed from the constant contact group to equalize the two groups' median age (two-point touch median age = 48; constant contact median age = 47).

Interactions

The advantage of the constant contact technique over the two-point touch technique was larger for those who had used the cane fewer than two years than for those with more experience. One hypothesis for such a result may be that it could take longer for someone to develop the perceptual abilities that are required to use the two-point touch technique effectively for detecting drop-offs than it takes to develop similar abilities that are needed for detecting drop-offs using the constant contact technique. This hypothesis could be supported if (1) cane users rely primarily on proprioceptive or kinesthetic feedback when using the two-point touch technique but on vibrotactile feedback when using the constant contact technique, and 2) it takes longer to improve proprioceptive or kinesthetic sensitivities than to improve vibrotactile sensitivities. However, we could not find published studies that examined the potentially different perceptual pathways that the two cane techniques rely on.

With respect to the extent of practice that is needed to improve different perceptual sensitivities, the results appeared mixed; most of the studies we found suggested that it does not take extensive practice to enhance vibrotactile sensitivities (Diespecker, 1970; Fucci et al., 1974; Godde et al., 1996; Maeda & Griffin, 1995; Schenkman, 1986), but there did not seem to be a consensus on the extent of practice that is needed to improve proprioceptive or kinesthetic sensitivities (Crilly et al., 1989; Graydon & Townsend, 1984; Islam et al., 2004; Sims & Morton, 1998; Wolf et al., 1997).

Strengths and limitations

The order effect was controlled for by randomly assigning the participants to one of the two conditions: the two-point touch technique first or the constant contact technique first. With regard to the main effect and simple effects of the within-group variable (type of cane technique used in drop-off detection), the mixed-measures design allowed each participant to serve as his or her own control for potential confounding.

One of the limitations of the study is related to the smooth walking surface that was used in the experiment. Although the study was not designed to determine whether increased surface irregularities have a negative effect on the detection of drop-offs, it is possible that such a potentially negative effect is larger for the constant contact technique than for the two-point touch technique, given the higher propensity for the cane to stick on rougher walking surfaces when the constant contact technique is used.

Another limitation of the study is related to the sample. A small sample that was obtained through a nonprobability sampling method limits the generalizability of the findings. In addition, despite the efforts to balance the groups with respect to important characteristics, such efforts were only partially successful. For example, although the age of the experienced cane users was similar to that of the inexperienced users, the median age difference between the cane users who used the two-point touch as the preferred cane technique and the group that used the constant contact as the preferred technique was significant. However, the confounding effect of age was modest at most.

Implications

The most important practical implication of the study is related to its potential contribution to the cane-training strategies that may be used by O&M specialists. For example, when drop-off detection is especially important, perhaps because of the cane user's poor balance, O&M specialists may consider recommending the constant contact technique, particularly in anticipation of curbs or substantial changes in the surface elevation in the environment.

O&M specialists also need to consider how much training time is available for a given consumer when devising appropriate cane training strategies. For example, many consumers who are visually impaired receive only a limited amount of O&M training, often because of a shortage of funding. Such occurrences are particularly common for nonvocational-track older consumers. Given the limited amount of authorized time for training, O&M specialists often need to determine which skills are priorities to teach during their limited training sessions. If such decisions need to be made in regard to cane training, particularly if detecting smaller drop-offs as well as larger ones is critical for the given consumer, O&M specialists may consider focusing their instruction on the constant contact technique, rather than attempting to have the consumer develop the ability to detect drop-offs adequately with both the two-point touch and the constant contact techniques. However, we do not suggest that the constant contact technique should be the primary cane technique taught to every long cane user. Rather, O&M specialists should assess each person's abilities and situation, as well as the merits and limitations of each technique, when determining which technique should be used in a given situation.

Recommendations

Future studies may be needed to examine the characteristics of users that may affect the detection of drop-offs, including the users' ages and ages at the onset of visual impairment. An investigation of how ergonomic factors (such as the type of cane tip and the length of the cane) and bio-mechanical factors (such as the width of the cane arc and the position of the cane-holding hand) affect the detection of drop-offs may also be useful. In addition, the inclusion of conditions in which a cane user approaches the drop-off at an acute angle may be necessary to reflect potentially dangerous real-world situations more fully (for example, approaching the edge of a train platform at 45 degrees). Furthermore, with a sufficient sample, analyses can be conducted to examine the relationships between the detection of drop-offs and specific predictor variables while controlling for the other variables in the model. Finally, it is necessary to examine multiple aspects of users' performance with a long cane, including the detection of obstacles, the discrimination of texture, and travel

efficiency, as well as drop-off detection, to determine the overall effectiveness of cane travel.

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Figure 1.
The testing condition.

Figure 2.

Interaction between years of cane use and the type of cane technique used in the drop-off detection trial.

Note: Error bars indicate 95% confidence intervals.

Table 1

Effects of the preferred cane technique, years of cane use, and the type of cane technique used on detecting drop-offs ($N = 32$).

Independent variables		50% detection threshold (inches)			Overall detection rate (%)			Large drop-off detection rate (%)		
		M	SD	p	M	SD	p	M	SD	p
Cane technique used in detection (within-group)	CC ($n = 32$)	1.65	.93		79.7	14.1		99.2	2.1	
	TT ($n = 32$)	2.91	1.14		62.9	12.7		93.4	12.2	
	Difference	-1.26	.91	<.001	16.8	10.9	<.001	5.8	11.3	.018
Preferred cane technique (between-groups)	CC ($n = 21$)	2.26	.94		71.1	12.3		95.5	7.6	
	TT ($n = 11$)	2.31	.97		71.6	12.7		97.7	4.4	
	Difference	-.05	.94	.886	-.5	12.4	.922	-2.2	6.7	.385
Years of cane use (between-groups)	2+ years ($n = 24$)	1.74	1.00		79.2	13.6		99.5	1.8	
	TT ^a	2.66	.97		66.3	11.9		96.6	6.6	
	Difference	-.92	.68	<.001	12.9	8.3	<.001	2.9	6.8	.046
Fewer than 2 years ($n = 8$)	CC ^a	1.40	.69		81.2	9.7		98.4	2.9	
	TT ^a	3.64	1.37		52.7	16.2		83.6	19.2	
	Difference	-2.24	.84	<.001	28.5	9.4	<.001	14.8	17.3	.046

Note. No three-way interaction was examined. CC = constant contact technique. TT = two-point touch technique.

^aThe cane technique that was used in drop-off detection. Given the absence of a significant interaction between the preferred cane technique and the type of cane technique used in drop-off detection, the main effects of these variables are reported. Given the significant interaction between years of cane use and the type of cane technique used in drop-off detection, simple effects of the type of cane technique used for each cane use year category are reported.