Published in final edited form as:

J Vis Impair Blind. 2009 September ; 103(9): 519–530.

Drop-off Detection with the Long Cane: Effects of Different Cane Techniques on Performance

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Abstract

This study compared the drop-off detection performance with the two-point touch and constant contact cane techniques using a repeated-measures design with a convenience sample of 15 cane users with visual impairments. The constant contact technique was superior to the two-point touch technique in the drop-off detection rate and the 50% detection threshold. The findings may help an orientation and mobility instructor select an appropriate technique for a particular client or training situation.

The core of modern long cane techniques, devised for blinded veterans by Richard Hoover in the 1940s (Miller & Hoover, 1946), has changed little since their development. Two long cane techniques, the two-point touch and the constant contact, are the most commonly used techniques by the majority of travelers who are blind (LaGrow & Weessies, 1994). The two-point touch technique—swinging the cane from side to side and tapping the edges of one’s walking path on either side in an arc slightly wider than one’s shoulders—has been the standard long cane technique for several decades (Hill & Ponder, 1976; Jacobson, 1993; LaGrow & Weessies, 1994; Miller & Hoover, 1946). The constant contact technique—sweeping the cane from side to side and keeping the cane tip in contact with the surface at all times (De Bruin, 1981)—is also widely used.

During the past six decades, only a handful of experimentally designed studies on the effectiveness of the two-point touch technique have been published. Bongers, Schellingerhout, van Grinsven, and Smitsman (2002) stated that the closer the cane tip stayed to the ground, the more obstacles the cane user detected, while LaGrow, Blasch, and De l’Aune (1997) indicated that when the cane-holding hand is held at the midline and positioned below the waist, the greatest detection distance of foot-level objects can be obtained. Wall and Ashmead (2002) found a negative correlation between the amount of movement of the cane-holding hand and the coverage of the walking path with the cane swing, while Uslan (1978) suggested that pivoting the elbow as well as the wrist of the cane-holding arm increases coverage of the walking path. In Fisk’s (1986) survey of 16 cane users, the respondents reported that in the constant contact technique, a cane equipped with a marshmallow tip (a cane tip made of nylon with a beveled end) was effective for detecting drop-offs. We found no published experimental design studies that examined the effectiveness of the constant contact technique either in relation to biomechanical or ergonomic factors or in comparison with the two-point touch technique.

One of the primary obstacles that has hindered empirical investigations of the effectiveness of long cane techniques is the lack of objective performance measures (Blasch & De l'Aune, 1992). Uslan (1978) operationally defined obstacle-detection performance using the percentage of the walking path covered by the trajectory of the cane. Uslan and Schriebman (1980) also defined successful drop-off detection as the prevention of overstepping—the cane tip's contact with the surface at or farther ahead of the area to be stepped on by the trailing foot. A more comprehensive framework for evaluating the effectiveness of long cane techniques was proposed in the 1990s (Blasch & De l'Aune, 1992; Blasch, LaGrow, & De l'Aune, 1996). Three suggested categories of performance outcomes were object preview, surface preview, and foot-placement preview (Blasch et al., 1996). *Object preview* is related to the reliable detection of obstacles on one's walking path, *surface preview* refers to the detection of changes in elevation and texture of one's walking surface, and *foot-placement preview* pertains to whether the cane tip has touched the surface area where the cane user's foot will be placed (Blasch et al., 1996).

Drop-off detection, a key component of surface preview (Blasch et al., 1996), is crucial for the safety of blind travelers, since missing drop-offs, such as curbs, may cause cane users to fall or stumble into the path of approaching vehicles. Missing a pothole or deeply sunken slab on the side-walk also poses a risk of falling and consequent fall-induced injuries. Drop-off detection with a long cane often requires not only contacting the sunken surface, but perceiving the difference in elevation. However, a cane user can also use kinesthetic feedback from the cane-holding hand to detect a drop-off before the cane tip strikes the sunken surface. That is, the cane tip falling below the level of the walking surface may cause the cane-holding wrist to extend farther downward, which, in turn, allows the cane user to recognize the presence of a drop-off by perceiving the change in the angle of the wrist.

Because no experimental studies have been conducted to examine the constant contact technique versus the two-point contact technique, the primary purpose of this study was to compare the thresholds and rates of drop-off detection using these two primary cane techniques. The secondary purpose was to explore how demographic and perceptual factors, such as age, onset of blindness, residual vision, and experience with using a cane, were related to the participants' performance in detecting drop-offs.

Method

STUDY DESIGN AND PARTICIPANTS

A repeated-measures design with block randomization was used for the study. We recruited 16 adults who were legally blind and had no other disabilities; 15 of the 16 completed the trials. All the participants had at least one month of long cane training and were familiar with and currently using both the two-point touch and the constant contact techniques.

APPARATUS

Six carpeted platforms (8 feet long, 4 feet wide, and 8 inches high) were built with plywood to form a 32-foot-long walkway. The first half of the walkway was 4 feet wide, and the second half, which led to the drop-off, was 8 feet wide. Two plywood boards (2 feet long and 4 feet wide) that were placed against one end of the walkway were used to vary the depth of the drop-off; carpeting on the plywood boards matched the carpeting on the walkway to prevent the participants from using tactile and auditory cues for detecting drop-offs. Each participant used a graphite rigid long cane (the Ambutech UltraLite Graphite Rigid Cane) with a marshmallow tip (the Ambutech MT4080 High Mileage Tip). Proper-length canes were selected for the participants according to their height; the proper length was defined as the vertical distance from the floor to 2 inches above the participant's

xiphoid process or the lower end of the sternum (LaGrow & Weessies, 1994). During the trials, the participants wore a full-size headphone set (RadioShack Full-Size Stereo Headphone 33-1225) connected to an MP3 player (Apple iPod 5th Generation), through which they heard regular beats over white noise (recorded by Sounds for Life). Background white noise prevented the participants from using auditory cues for detecting drop-offs, while the regular beats (90–110 beats per minute) helped each participant walk at a consistent pace throughout the trials. A digital camcorder (Panasonic SDR-S10P1) was used to record each trial.

RESEARCH PROCEDURE

The test site was an 8-foot-wide concrete hallway in the basement of a building at Western Michigan University (WMU). Upon arriving at the site, each participant signed the informed consent form approved by WMU's Human Subjects Institutional Review Board. The participants learned about the test site and experimental procedure through verbal briefing on trial procedures and two practice trials. Each participant wore sleep shades and a headphone set during all the trials. On the basis of the participants' comfortable stepping speed, the experimenter (a certified orientation and mobility, O&M, specialist) set the speed of the beats, to which the participants synchronized their steps. The researchers noted that most participants appeared to walk in somewhat short strides during the trials, relative to their steps when walking before the trials began, since they knew they were approaching drop-offs that were up to 7 inches deep. Consequently, almost all the recorded misses in detecting drop-offs in this study would be the result of failure to recognize the presence of the drop-off, rather than a result of late detection of the drop-off, in contrast with some previous studies that used the distance between the edge of the drop-off and where the participant stopped (upon detecting the drop-off) as a measure of the detection of drop-offs (Bongers et al., 2002; Schellingerhout, Bongers, van Grinsven, Smitsman, & van Galen, 2001). The method for measuring the detection of drop-offs that was used in our study preserves the inherently dichotomous nature of the variable (detected versus missed).

The first author positioned each participant at the center of the walkway and properly aligned the participant with the walkway. Starting points were randomly selected from 14 to 30 feet from the drop-off for each trial to prevent the participants from anticipating the drop-off at a predictable distance. At a signal from the experimenter, the participant walked toward the drop-off using either the two-point touch technique or the constant contact technique. Upon detecting the drop-off, the participant was told to stop immediately and say "drop-off." The experimenter walked behind the participant to help if he or she stumbled off the walkway. Upon completion of each trial, the experimenter guided the participant to the next starting point, walking in an irregular zigzag pattern to prevent the participant from knowing how far the next starting point was from the drop-off.

The participants had one practice drop-off detection trial for each cane technique. Each participant completed 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) for a total of 64 trials per participant. The effect of the order of presentation was controlled by randomly assigning participants to use either the two-point touch or the constant contact technique first. Research assistants varied the height of the piles of plywood boards that were placed against the walkway so that the drop-off depth ranged from 1 to 7 inches with 2-inch increments. The block-randomization method was used to randomly select the drop-off depth for each trial.

A research assistant recorded a trial as a miss if the participant stepped off the walk-way or would have fallen off the drop-off had the experimenter not intervened. Such intervention was necessary to prevent injuries when large drop-offs were presented. Occasionally, a

participant's cane tip extended beyond the lower plywood surface, touching the farther edge of the plywood pile or the cement floor beyond. The failure to stop upon contacting the surface of the sunken plywood pile, even when the participant stopped upon tapping the farther edge of the plywood pile or cement floor, was recorded as a miss. We categorized such trials as a miss because the participant never noticed the presence of the drop-off even upon contacting the presented sunken surface and continued walking until he or she touched what was beyond the presented surface. All other trials in which the participant stopped before falling off the drop-off were recorded as the successful detection of a drop-off. An independent rater scored a random selection of one-third of the trials by watching a prerecorded video; interrater reliability was 98%. On-site records were used when there was a discrepancy.

VARIABLES

We used the absolute drop-off detection threshold (50%) and drop-off detection rates to measure the participants' drop-off detection performance (the dependent variable). A 50% absolute threshold is one of the most commonly used measures of sensory sensitivity (Gescheider, 1997). A 50% absolute drop-off detection threshold is the smallest drop-off depth that can be detected at least 50% of the time. We calculated the 50% absolute drop-off detection threshold for each technique using the psychometric function outlined in Gescheider (1997). We calculated the drop-off detection rates by dividing the total number of detections by the total number of trials. The type of cane technique (the two-point touch or constant contact) was the independent variable.

ANALYSIS

A series of descriptive statistical procedures were used to examine the distributions of variables, outliers, missing data points, and general bivariate correlations. No assumptions other than interval-level data and a linear relationship between the compared variables were necessary for using the Pearson's product-moment correlation because the procedure was used to describe the data on the sample, rather than to make an inference about the population (Cohen, Cohen, West, & Aiken, 2003).

Psychophysical measurements, including sensory sensitivity, tend to be normally distributed among a population (Gescheider, 1997; Goldstein, 2007). Upon completing the descriptive statistical procedures, we used within-subjects *t*-tests to determine whether there was a difference in the drop-off detection threshold between the two-point touch and the constant contact techniques. Given the positive skewness of the difference in the drop-off detection rates between the two techniques, we used the Wilcoxon signed rank test to determine whether there was a difference in the drop-off detection rates of the two techniques. We used a significance level of .05 for all statistical tests (two tailed) in this study. The a priori statistical power of the *t*-tests was .82 when a large effect size ($d = .8$) was assumed (Cohen, 1988; Erdfelder, Faul, & Buchner, 1996). All statistical analyses were conducted with SPSS version 14.0 for Windows Grad Pack and G*Power.

Results

DEMOGRAPHIC CHARACTERISTICS OF THE PARTICIPANTS

Ten men and 5 women with visual impairments, aged 20–61 (median age = 30), participated in the study. Their visual acuities ranged from no light perception to 20/200. The etiologies of the participants' visual impairments included retinitis pigmentosa ($n = 3$), glaucoma ($n = 2$), retinal detachment ($n = 2$), diabetic retinopathy ($n = 1$), uveitis ($n = 1$), retinal dysplasia ($n = 1$), malnutrition ($n = 1$), and unknown etiology ($n = 4$). All the participants used the long cane as their primary mobility aid; two participants used the two-point touch technique

more frequently (90%–95% of the time), while the other participants used the constant contact technique more often (75%–95% of the time, median = 85%). The participants' experience in using the long cane varied from 1 month to 36 years (median = 7 years). Six participants stated that they traveled independently almost every day, 3 stated that they traveled 1 to 5 days per week, and 6 stated that they did not travel independently. The extent of training in O&M varied from 1 month to 13 years of at least weekly instruction (excluding summer and winter breaks).

COMPARISON OF TECHNIQUES

As is shown in Figure 1, the drop-off detection threshold of the two-point touch technique (2.9 inches) was significantly larger than that of the constant contact technique (1.5 inches), $t(14) = 5.98$, $p < .001$. That is, the participants were able to detect much smaller drop-offs when they used the constant contact technique than when they used the two-point touch technique.

The overall drop-off detection rate of the two-point touch technique (62.5%) was significantly lower than that of the constant contact technique (82.7%), $z = -3.301$, $p = .001$. In other words, the participants were able to detect more drop-offs with the constant contact technique than with the two-point touch technique. As Figure 2 shows, the difference in the drop-off detection rates of the two techniques was greater for the smaller drop-offs (for example, 35.0% for the 1-inch drop-off) than for the larger drop-offs (for instance, 7.5% for the 7-inch drop-off).

Assuming conservatively that only drop-offs that are at least 5 inches deep pose a serious risk of causing one to lose one's balance or fall, we compared the drop-off detection rates of the two techniques for the 5- and 7-inch drop-offs. Even for these large drop-offs, the drop-off detection rate with the constant contact technique (99.2%) was significantly higher than that with the two-point touch technique (90.0%), $z = -2.384$, $p = .017$. These results indicate that the participants were able to detect at a higher percentage not only the small drop-offs, but the large ones, with the constant contact technique, albeit with a declining advantage with drop-offs of greater depth.

As Figure 3 shows, the smallest drop-off that the participants could detect (the threshold) grew larger with age, regardless of which technique the participants used ($r = .655$ for the constant contact technique, $r = .532$ for the two-point touch technique). In contrast, Figure 4 shows that the smallest drop-off that the participants could detect grew smaller with increasing experience in using a cane ($r = -.593$ for the constant contact technique, $r = -.460$ for the two-point touch technique).

Table 1 shows the relationship between some of the individual characteristics of the participants, including visual acuity, onset of visual impairment, independent travel, and primary cane technique, and the participants' performance in detecting drop-offs. For interpreting the results in Table 1, we direct the readers' attention to the fact that these are simple descriptions of the data from the sample from which we made no inference to the corresponding population. Compared to those with more functional vision, the participants who had little functional vision (no light perception or light perception) could detect drop-offs that were smaller. This difference was larger for those who used the two-point touch technique (0.87 inches) than for those who used the constant contact technique (0.56 inches). Table 1 also shows that the participants who were congenitally blind outperformed those who were adventitiously blinded in each technique and that the participants who traveled independently at least one day a week performed better in detecting drop-offs than did those who traveled less frequently or not at all. However, the drop-off detection performance was similar for the participants who primarily used the two-point touch

technique and those who mostly used the constant contact technique. As can be seen in Table 1, the constant contact technique's advantage over the two-point touch technique was greater for the group who preferred the two-point touch technique (2.03 inches, $n = 2$) than for the group who preferred the constant contact technique (1.36 inches, $n = 13$).

Discussion

COMPARISON OF CANE TECHNIQUES IN DETECTING DROP-OFFS

We measured the participants' performance in detecting drop-offs not only by the percentage of detection, but by the detection threshold. This approach allowed us to examine how small a drop-off each cane technique could detect; no previous studies have examined these thresholds. The two-point touch technique's drop-off detection threshold of 3 inches, which is twice as large as that of constant contact technique, poses a safety concern for cane users because it translates into missing drop-offs that are 3 inches deep half the time. Missing a 3-inch drop-off may cause an individual to lose his or her balance or even fall, especially if the cane user is older or less coordinated.

Overall, the participants missed more than 1 in 3 drop-offs when they used the two-point touch technique, but fewer than 1 in 5 drop-offs when they used the constant contact technique; most of the misses with the constant contact technique were for 1-inch and 3-inch drop-offs. For the large drop-offs (5 or 7 inches), which are likely to cause falls if missed, the participants still missed 1 in 10 drop-offs with the two-point touch technique, but fewer than 1 in 100 drop-offs were missed with the constant contact technique. These results indicate that the difference in detecting drop-offs between the two cane techniques is significant not only statistically but also practically.

Although our study did not allow us to determine why the constant contact technique was better than the two-point touch technique for detecting drop-offs, one hypothesis could be the participants' reliance on different perceptual pathways. When using the two-point touch technique, cane users may rely primarily on kinesthetic feedback—the angle of the wrist or the position of the cane-holding hand—for detecting drop-offs. In contrast, when they use the constant contact technique, although kinesthetic perception is also involved, vibrotactile perception may play a major role in detecting drop-offs. In other words, when a cane user sweeps his or her cane from side to side, the vibration he or she feels through the cane-holding hand varies little; then when the cane tip passes the drop-off edge, the cane user feels a momentary relief of pressure on his or her cane-holding hand (while the cane tip drops downward), which is immediately followed by a distinctly higher intensity of pressure when the cane tip lands on the sunken surface.

DEMOGRAPHIC FACTORS RELATED TO DETECTING DROP-OFFS

The superior performance in detecting drop-offs by the participants with longer years of cane use is consistent with the literature on the relationship between training and perceptual abilities: training can improve perception (Platt & Racine, 1985; Recanzone, Merzenich, & Jenkins, 1992; Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000). Enhanced kinesthetic and vibrotactile perceptual abilities acquired through practice (Fleischman & Rich, 1963; Morford, 1966; Sims & Morton, 1998) may have enabled the participants with more experience in using long canes to outperform those with less experience.

The inferior performance in detecting drop-offs by the older participants is also consistent with the literature on the relationship of age to perceptual abilities. Perceptual sensitivity generally deteriorates with age (Dyck, Karnes, Bushek, Spring, & O'Brien, 1983; Meeuwssen, Sawicki, & Stelmach, 1993; Verrillo, 1993). Such age-related declines in

kinesthetic and vibrotactile sensitivity (Adamo, 2007; Hurley, Rees, & Newham, 1998; Van Hedel & Dietz, 2004) may have contributed to the older participants' weaker performance in detecting drop-offs. It is worth noting that age and experience in using a cane did not closely correlate with each other ($r = -.230$), which indicates a limited potential for a confounding effect of age on the relationship between experience in using a cane and the ability to detect drop-offs.

LIMITATIONS

This study had many limitations. First, its small convenience sample limits the generalizability of the findings. In particular, we included only a small number of older persons who were visually impaired, who constitute the majority of new cane users. Second, only 2 of the 15 participants used the two-point touch technique as their primary cane technique. Third, the potential for a confounding effect between the characteristics of users (such as age, onset of visual impairment, and experience) was not controlled for. Fourth, the researchers were not blinded to the experimental conditions, including technique and depth of the drop-off. As a result, the outcome of the study might have been influenced by observer bias. Fifth, in this study, the participants who walked at a naturally slower pace than others might have had a perceptual advantage in detecting drop-offs.

Another limitation of the study was related to our exclusion of the "observer's criterion" (Gescheider, 1997). In other words, a few conservative participants—those who were cautious—indicated, albeit infrequently, the presence of a drop-off even when they were not within reach of the drop-off: a false positive trial. The performance of the participants who had false positive trials could have been inflated in relation to those with no false positive trials, albeit negligibly, given the limited number of false positives for any participant.

The difference in the lengths of the canes that the participants used in their daily travel and the canes that they used during the trials might have affected their performance in detecting drop-offs. However, such an effect does not appear to have been large, given the low correlations between the difference between the length of canes and the drop-off detection thresholds ($r = -.041$ for the constant contact technique, $r = -.145$ for the two-point touch technique). In addition, although all the participants had been taught both cane techniques by their O&M instructors, the instructors' preferences and the resulting emphasis on one technique over the other during O&M training might have influenced the results of the study. Which technique the participant used as the primary cane technique might have also affected the results for detecting drop-offs, although in our sample the advantage of the constant contact technique in detecting drop-offs was present regardless of the participants' primary cane technique.

IMPLICATIONS

In practice, given the results of this study, O&M specialists should not automatically expect their clients, particularly those who are less experienced or older, to be able to detect small drop-offs with the two-point touch technique. If it is crucial for a client's safety to detect small as well as large drop-offs because of poor balance, for example, an O&M specialist may need to consider suggesting that the client use the constant contact technique primarily. In addition, these preliminary data suggest that the two-point touch technique is relatively unreliable in its ability to detect drop-offs; thus, O&M specialists may consider suggesting that cane users switch to the constant contact technique when they anticipate a drop-off (for example, when they approach the end of a block), particularly in the presence of drop-offs that are less pronounced. That being said, we do not interpret the findings to suggest that the constant contact technique should be the primary cane technique taught to every client. Rather, it seems that a thoughtful consideration of the pros and cons of each cane technique,

as well as a client's abilities and situation, be taken into account when deciding which cane technique should be used in a given situation.

RECOMMENDATIONS

With a larger sample size, interactions between the predictor variables (such as the cane technique and experience in using a cane) can be examined in future studies. Such investigations may provide important practical implications for O&M specialists in their decision to choose techniques for clients, depending on the available amount of time for training.

Considering the often-cited problem of "sticking" (when the cane tip becomes lodged in a crack between pavement stones, for example) that sometimes accompanies the constant contact technique, a comparison of a client's performance in detecting drop-offs using a standard tip and a modified tip (for example, a roller tip or ball tip) may also have important practical implications. In addition, with a sufficient sample size, researchers can conduct analyses to examine the relationships between detecting drop-offs and specific predictor variables while controlling for the other variables in the model.

Last, drop-off detection is only one of many possible performance outcome measures of a long cane technique. Therefore, in future studies, it will be necessary to examine other cane performance outcomes, such as obstacle-detection rates and performance efficiency, to determine the overall effectiveness of each cane technique.

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Figure 1.
50% Absolute drop-off detection thresholds. Error bars indicate 95% confidence intervals.

Figure 2.
Drop-off detection rates, by techniques.

Figure 3.
Correlations between age and 50% absolute detection thresholds.

Figure 4.
Correlations between cane use experience and 50% absolute detection thresholds.

Table 1

Characteristics of participants in relation to drop-off detection thresholds (in inches; *SD* in parentheses).

Variables	Categories	Two-point touch: TT (<i>N</i> = 15)	Constant contact: CC (<i>N</i> = 15)	TT-CC (<i>N</i> = 15)
Visual acuity	NLP/LP (<i>n</i> = 8)	2.50 (1.05)	1.19 (.69)	.31 (.91)
	Other (<i>n</i> = 7)	3.37 (1.50)	1.75 (.87)	1.62 (1.02)
Onset of visual impairment	Congenital (<i>n</i> = 5)	2.24 (.56)	1.01 (.30)	1.23 (.49)
	Adventitious (<i>n</i> = 10)	3.24 (1.47)	1.67 (.90)	1.57 (1.11)
Independent travel	Yes (<i>n</i> = 10)	2.54 (.90)	1.26 (.70)	1.28 (.72)
	No (<i>n</i> = 5)	3.63 (1.79)	1.83 (.93)	1.80 (1.31)
Primary cane technique	Two-point touch (<i>n</i> = 2)	3.41 (1.34)	1.38 (1.25)	2.03 (.10)
	Constant contact (<i>n</i> = 13)	2.83 (1.34)	1.47 (.79)	1.36 (.98)

NLP = no light perception; LP = light perception.