Analysis of Factors Related to Drop-Off Detection with the Long Cane

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ANALYSIS OF FACTORS RELATED TO DROP-OFF DETECTION WITH THE LONG CANE

by

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The purpose of this dissertation was to examine the three key factors related to drop-off detection with the long cane: (1) cane-technique-related factors, (2) user characteristics, and (3) ergonomic factors. A mixed-measures design with block randomization was used for the study, in which 32 visually impaired adults with no other disabilities attempted to detect the drop-offs using either the two-point touch technique or the constant contact technique.

Participants detected drop-offs at a significantly higher percentage when they used the constant contact technique (78.3%) than when they used the two-point touch technique (62.1%), \( p < .001 \). The 50% absolute drop-off detection threshold of the constant contact technique (1.65") was also significantly smaller than that of the two-point touch technique (2.91"), \( p < .001 \). Constant contact technique’s advantage in overall drop-off detection rate over the two-point touch technique was significantly larger for the less experienced cane users (difference of 26.2%) than for more experienced cane users (difference of 12.9%), \( p = .001 \). Constant contact technique’s advantage over the two-point touch technique changed little even when the constant contact technique was used with the tip that was perceived to be disadvantageous for drop-off detection (marshmallow roller tip) (76.7% detection rate), while the two-point
touch technique was used with the tip that was perceived to be more advantageous for drop-off detection (marshmallow tip) (61.8%), \( p < .001 \).

In respect to user characteristics, younger cane users (72.8%) detected drop-offs significantly better than older cane users (60.9%), \( p = .044 \). In addition, those who lost their vision early in life (78.0%) performed significantly better than those with later-onset visual impairment (65.5%), \( p = .012 \).

The findings of the study may help cane users and orientation and mobility specialists select appropriate cane techniques in accordance with the cane user’s characteristics, availability of training time, and the nature of the travel environment. Future studies are needed to examine multiple aspects of long cane performance, which include obstacle detection, texture discrimination, and travel efficiency, as well as drop-off detection, in order to determine the overall effectiveness of cane travel.
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Dedicated to my wife, Hisun, and my daughter, Genevieve
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CHAPTER I

INTRODUCTION

This dissertation, conducted as the second phase study of a preliminary study (Kim, Wall Emerson, & Curtis, in press) with additional analyses of the combined data, examines some of the factors related to drop-off detection with the long cane. It is composed of five chapters and employs a three-paper method; each of the three chapters in the body of the dissertation (chapters II, III, and IV) is written as a stand-alone article. The introduction chapter (chapter I) provides an overall framework for the three manuscripts, while the conclusion chapter (chapter V) discusses the collective implications of the findings from the three chapters as well as provides recommendations for future research.

Use of the Long Cane for Drop-off Detection

The design of the modern long cane along with the techniques to use it effectively was developed during World War II (Miller & Hoover, 1946). The two-point touch technique and the constant contact technique are the two most common long cane techniques used by blind travelers (LaGrow & Weessies, 1994). Two-point touch technique—swinging the cane to tap the edges of a cane user's walking path in an arc a few inches wider than one's body width—has been the standard long cane technique since its development during World War II (Hill & Ponder, 1976; Jacobson, 1993; LaGrow & Weessies, 1994; Miller & Hoover, 1946). Constant contact technique—
sweeping the cane from side to side in an arc a few inches wider than one’s body width while keeping the cane tip in constant contact with the walking surface (De Bruin, 1981)—is also widely used by blind travelers.

No matter what cane technique is used, it is critical for blind travelers to reliably detect changes in elevation of the walking surface. Detecting depressed surfaces (e.g., down-curb) is often more difficult than detecting elevated surfaces (e.g., up-curb) of comparable height since a depressed surface does not tend to abruptly stop cane’s forward movement, whereas an elevated surface often does. Missing a depressed surface (drop-off) may result in serious consequences. For example, a cane user may fall or accidentally put himself in the collision path of an oncoming vehicle by missing a curb (Uslan & Schriebman, 1980). Failure to detect uneven surfaces (e.g., a pothole or sunken slab) on the sidewalk may also result in falls and consequent fall-induced injuries (Uslan & Schriebman, 1980). For these reasons, drop-off detection is considered one of the key functions of a long cane (Blasch, LaGrow, & De l’Aune, 1996).

In an effort to enhance a cane user’s ability to detect drop-offs with the long cane using kinesthetic/propr ioceptive feedback, Orientation and Mobility (O&M) specialists stress the importance of restricting the cane swing movement to the wrist rather than allowing the whole arm to move with each cane swing (Hill & Ponder, 1976). In addition, in an attempt to systematically develop cane users’ abilities to detect drop-offs, O&M specialists try to introduce novice cane users to an environment where there are easily detectable drop-offs such as prominent curbs and stairs before exposing them to situations in which they need to detect more subtle drop-offs (“Cane Technique,” 1992).
Factors Related to Drop-off Detection

A number of factors can affect drop-off detection performance, but for the purpose of systematically comparing the two cane techniques (two-point touch, constant contact), they may be classified into four main categories: cane-technique-related factors, user characteristics, ergonomic factors, and environmental factors (see Figure 1-1). As a first step to understand how these factors affect drop-off detection, this dissertation examines the factors that are either inherent to or controllable by the cane user (cane-technique-related, user characteristics, ergonomic), while leaving the investigation of environmental factors for future research.

Examination of cane-technique-related factors is important not only because different cane techniques may involve different biomechanical movements of the body, but also because they may rely on different sensory channels for detecting drop-offs. Investigation of how cane technique practice affects drop-off detection is also important because training can often improve human perceptual abilities (Platt & Racine, 1985; Recanzone, Merzenich, & Jenkins, 1992; Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000), thus reducing detection failure and helping prevent injuries. This dissertation examines the following three cane-technique-related factors: (1) type of cane technique used in drop-off detection, (2) preferred cane technique, and (3) amount of cane technique practice.

Along with the cane techniques, user characteristics, including age and age at onset of visual impairment, may also affect drop-off detection performance. Aging is associated with a decline in perceptual sensitivities (Goble, Coxon, Wenderoth,
Factors Related to Drop-off Detection

Cane-technique-related Factors

User Characteristics

Ergonomic Factors

Environmental Factors

Preferred Technique

Age of Cane User

Type of Cane Tip

Amount of Practice

Age at Onset of Visual Impairment

Cane Length

Type of Technique Used in Drop-off Detection

Level of Functional Vision

Cane Shaft Material

Note. Factors examined in this dissertation have been shaded. Classification of the factors into these four categories was made for the purpose of systematically comparing the two cane techniques (two-point touch, constant contact). “Type of Cane Technique Used in Drop-off Detection” was bolded to indicate the fact that all the other factors were examined in the context of which cane technique was used in drop-off detection.

Figure 1-1. Overview of Factors Related to Drop-off Detection Performance

Van Impe, & Swinnen, 2009; Owsley, 1983; Verrillo, 1993). In addition, age-induced deterioration of perceptual sensitivities appears to manifest itself in all sensory modalities, including proprioceptive/kinesthetic (Pai, Rymer, Chang, & Sharma, 1997; Skinner, Barrack, & Cook, 1984) and vibro-tactile (Gescheider, Edwards, Lackner, Bolanowski, & Verrillo, 1996; Stevens & Foulke, 1996) senses, which seem to be closely related to the ability to detect drop-offs with the long cane. Aging also tends to impair one’s sense of balance (Wolfson, 2001), and increase postural sway during walking.
Increased variability in motor trajectory may negatively affect one's ability to detect subtle changes in body position (e.g., changes in wrist and elbow angles of the cane-holding hand) using predictable proprioceptive/kinesthetic feedback (Turvey & Carello, 1995).

Another user characteristic that is important to examine is age at onset of visual impairment because there appear to exist distinct sensitive (critical) periods that allow full development of perceptual abilities (Blakemore & Cooper, 1970; Crair, Gillespie, & Stryker, 1998; Hirsch & Spinelli, 1970; Rauschecker, 1999). Different sensitive periods seem to exist for different sensory modalities (de Schonen, Mancini, Camps, Maes, & Laurent, 2005; Sathian, 2005). For example, sensitive period for stereoacuity appears to span from 3 months to 36 months (Birch & Hale, 1989), while the maximally plastic period for the development of central auditory system seems to end at age 7 (Sharma, Dorman, & Spahr, 2002). Drever (1955) suggested that the optimal period for kinesthetic sensitivity development ends at age 4, while Facchini and Aglioti (2003) reported a presence of effective vibro-tactile learning abilities even in adulthood. Given such, this dissertation examines, along with the cane technique, the effect of cane user's age and age at onset of visual impairment on drop-off detection.

Last, it is crucial to explore how ergonomic factors related to the long cane use affect drop-off detection. For example, it is important to investigate how different cane tips affect drop-off detection since a cane tip, being the part of the cane that makes contact with the walking surface, plays a key role in transmitting vibro-tactile feedback to the cane user (National Academy of Sciences, 1972; Veterans Administration, 1964). Cane tips also seem to affect the frequency of sticking against the walking surface (Lillie,
1987; Pietrowicz, 1987; Robertson, 1987; Rodgers, 1991; Wang, 1991), which may influence drop-off detection performance. Yet, their effect on drop-off detection has not been fully investigated.

Since many cane tips are made with a particular cane technique in mind, it is important to examine the effect of cane tips in conjunction with the cane technique used in drop-off detection. The need for such investigation is further warranted by the presence of cane technique’s significant effect on drop-off detection performance (Kim et al., in press). Accordingly, this dissertation examines the effect of cane tips on drop-off detection in combination with the type of cane technique used in drop-off detection.

For the most useful practical implications, not only the type of cane tip, but also all the other factors that are included in this dissertation, need to be examined in the context of which cane technique should be selected for an individual in a given situation. Although all of these factors may affect drop-off detection performance, while a cane user can readily select which cane technique to use for detecting drop-offs, he or she does not have control over most of the other factors, including age, age at onset of visual impairment, preferred cane technique, and amount of cane technique practice (years of cane use).

The aim of this dissertation is to further our understanding of how cane-technique-related factors, user characteristics, and ergonomic factors affect drop-off detection with the long cane. Better understanding of how these factors affect drop-off detection is important for facilitating Orientation and Mobility specialists’ efforts to develop appropriate cane training strategies in accordance with each consumer’s characteristics and specific training situations.
References


CHAPTER II

ANALYSIS OF CANE-TECHNIQUE FACTORS RELATED TO DROP-OFF DETECTION WITH THE LONG CANE

The two-point touch and constant contact techniques are the two long cane techniques most widely used by blind travelers (LaGrow & Weessies, 1994). Two-point touch technique—moving the cane from side to side to touch the edges of one’s walking path in an arc a few inches beyond the widest part of one’s body—has been widely used by blind travelers since its development during World War II (Hill & Ponder, 1976; Jacobson, 1993; LaGrow & Weessies, 1994; Miller & Hoover, 1946). Constant contact technique—moving the cane from side to side while maintaining the cane tip’s contact with the walking surface at all times (De Bruin, 1981)—is also commonly used by blind cane users.

A blind cane user’s ability to reliably detect drop-offs such as curbs is critical for preventing falls or accidental stumbling into the collision path of an oncoming vehicle (Uslan & Schriebman, 1980). A blind cane user may also fall and receive fall-induced injuries by failing to detect uneven surfaces (e.g., a pothole or sunken slab) on his walking path (Uslan & Schriebman, 1980). Given such importance, drop-off detection is considered one of the key factors that determine the effectiveness of the long cane use (Blasch & De l’Aune, 1992; Blasch, LaGrow, & De l’Aune, 1996)

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

In addition, training 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/kinesthetic and vibro-tactile 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 (five blindfolded trials in each session), 10 adolescent girls showed a significantly improved accuracy in badminton short serve (Graydon & Townsend, 1984), while 50 undergraduate students demonstrated a significantly higher accuracy in discriminating the intensity and duration of vibro-tactile stimuli applied to one of the five locations in their arms (fingertips, palm, wrist, forearm, upper arm) after a single session of 10 trials (Diespecker, 1970). The preliminary study by Kim et al. (in press) also showed a positive correlation between the amount of cane technique practice and drop-off detection performance. However, it was a simple description of the sample data, from which no inference to the corresponding population was made.

Some orientation and mobility (O&M) specialists have stated that blind travelers who use the two-point touch technique as their preferred cane technique show better
overall drop-off detection performance than those whose preferred technique is the
constant contact technique (M. J. Weessies, personal communication, February 4, 2009;
S. Williams-Riseng, personal communication, January 31, 2009). They further stated that
the cane users who use the two-point touch technique as their preferred cane technique
tend to be the ones who are more experienced in cane use. However, no published studies
have previously investigated this topic using an experimental design.

Enhancing vibro-tactile sensitivity does not appear to require extensive practice
(Diespecker, 1970; Fucci, McCaffrey, Curtis, & Blackmon, 1974; Godde, Spengler, &
Dinse, 1996; Maeda & Griffin, 1995; Schenkman, 1986), while the results seem mixed in
respect to the amount of practice needed to improve proprioceptive and kinesthetic
sensitivities (Crilly, Willems, Trenholm, Hayes, & Delaquerriere-Richardson, 1989;
Graydon & Townsend, 1984; Islam et al., 2004; Sims & Morton, 1998; Wolf, Barnhart,
Ellison, & Coogler, 1997). In addition, some O&M specialists have stated that it takes
longer for many cane users to become competent in drop-off detection with the two-point
touch technique than with the constant contact technique (M. J. Weessies, personal
communication, February 4, 2009; R. O. LaDuke, 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 drop-off detection.

One of the primary purposes of the present study was to determine whether the
constant contact technique’s advantage over the two-point touch technique in drop-off
detection (Kim et al., in press) could be supported when a more balanced sample—
particularly in respect to participants’ preferred cane technique—was used. Another key
purpose of the study was to more closely examine how practice and preferred cane
technique affect drop-off detection performance. This study also investigated the interaction between amount of cane technique practice and the type of cane technique used in drop-off detection, as well as the interaction between preferred cane technique and the type of cane technique used in drop-off detection.

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 disabilities, familiarity with both the two-point touch and constant contact techniques, and a minimum of 1-month-long cane training. Although not a requirement, efforts were made to acquire a balanced sample in respect to age, cane use experience, and preferred cane technique.

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., in press)—in respect to preferred cane technique, age, and amount of practice. Identical recruitment criteria and experimental protocol allowed the combination of the data from the preliminary study of 15 participants with those from the latest 17 for the analysis.
Apparatus

Six carpeted plywood platforms (8 feet long, 4 feet wide, 8 inches high) supported by 2 × 4 braces formed a 32-foot-long walkway (see Figure 2-1). The first 16 feet of the walkway was 4 feet wide, while the latter half of the walkway was 8 feet wide, filling the entire width of the hallway where the experiment was conducted. Two plywood boards (2 feet long, 4 feet wide) placed on top of braced rectangular frames (2 feet long, 4 feet wide, 2 inches high) were used to change the drop-off depth at the end of the walkway from trial to trial. Carpeting on the plywood boards matched the carpeting on the walkway to prevent the participants from using tactile and/or auditory cues for drop-off detection.

Figure 2-1. Participant Approaching the Drop-off on the 32-Foot-Long Walkway Used in the Study
Participants used identical canes of different lengths (Ambutech UltraLite Graphite Rigid Cane) with identical cane tips (Ambutech MT4080 High Mileage Tip). A participant’s cane length was assigned based on height; vertical distance from the ground to 2 inches above the participant’s xiphoid process was used for selecting the cane length for the participant (LaGrow & Weessies, 1994). A digital camcorder (Panasonic SDR-S10P1) was used to record each trial. Further details of the apparatus and research procedure are available in Kim et al. (in press).

Research Procedure

All experiments were conducted in Western Michigan University’s College of Health and Human Services building basement hallway. 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 trials. Through the headphone set, rhythmic beats (90–110 beats per minute) were played over a white noise background. The experimenter (a Certified O&M Specialist) adjusted the speed of the rhythmic beats in accordance with each participant’s relaxed stepping speed. Participants were instructed to synchronize their steps to the beats during all trials. Such synchronization was aimed at having the participant walk at a consistent pace throughout the trials, which was an effort to limit the potential confounding effect of walking speed on drop-off detection.

To keep participants from estimating the distance to the drop-off, starting points (14 to 30 feet from the drop-off) were randomly selected for each trial. Upon receiving a signal from the experimenter, a participant walked towards the drop-off using either the
two-point touch technique or the constant contact technique, according to the randomized schedule of trials. Participants were instructed to stop instantly and indicate the presence of a drop-off if a drop-off was detected.

Eight trials for each drop-off depth (1", 3", 5", 7") using each technique (two-point touch, constant contact) resulted in a total of 64 trials per participant. Drop-off depth for each trial was randomly selected by the block randomization method. If the participant fell off the drop-off or would have fallen off the drop-off had it not been for the intervention of the experimenter, the trial was regarded as a miss. Interrater reliability for drop-off detection was 98% in a preliminary study (Kim et al., in press).

Variables

Absolute drop-off detection threshold (50%) and drop-off detection rates were used to measure participants' drop-off detection performance (dependent variables). We calculated the 50% absolute drop-off detection threshold for each technique using the psychometric function outlined in Gescheider (1997, pp. 45-48). In other words, a cumulative normal distribution curve was fitted to the detection rate of each drop-off depth (1", 3", 5", 7") to extrapolate the depth that was detected 50% of the time. Overall drop-off detection rate was calculated by dividing the total number of detections by total number of trials. Large drop-off detection rate was computed in a similar manner, but only with 5 and 7 inch drop-off detection rates combined.

Type of cane technique used in drop-off detection trial (within-group variable with two categories: two-point touch, constant contact), years of cane use (between-groups variable with two categories: 2 years or longer, less than 2 years), and preferred
cane technique (between-groups variable with two categories: two-point touch, constant contact) were the independent variables of the study.

Analysis

A series of descriptive statistical procedures—histograms, scatter plots, and measures of central tendency and dispersion—were performed as a preliminary step. Upon completion of descriptive statistical procedures, a two-way mixed-measures analysis of variance (ANOVA) was used to test the hypotheses; three-way interaction was not examined due to limited interpretability and practical benefits. In the presence of significant interactions, simple effects rather than main effects were examined (Keppel, 1991). The Welch procedure (1951) was used when the homogeneity of variance assumption was violated.

We tested the following two specific interactions: (1) years of cane use × type of cane technique used in drop-off detection, and (2) preferred cane technique × type of cane technique used in drop-off detection. The interaction between the two between-groups variables—years of cane use × 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 this study. Statistical powers of the main effect, simple effect, and interaction effect tests 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

Participant Demographics

Eighteen male and 14 female adults participated. Visual acuities ranged from no light perception to 20/200. Etiologies of participants' visual impairment 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 \((n = 14)\). Participants' ages ranged from 20 to 75 \((Mdn = 37)\). All participants used the long cane as their primary mobility aid; 11 participants used the two-point touch technique more frequently \((60–95\% \text{ of the time}, Mdn = 75\%, Mdn \text{ Age} = 48)\), while the remainder used the constant contact technique more often \((60–95\% \text{ of the time}, Mdn = 85\%, Mdn \text{ Age} = 30)\). The experienced cane user group’s \((n = 24)\) duration of cane use was at least 2 years and spanned up to 42 years \((Mdn = 14 \text{ years}, Mdn \text{ Age} = 36)\), while the inexperienced group’s \((n = 8)\) duration of cane use ranged from 1 month to 13 months \((Mdn = 2 \text{ months}, Mdn \text{ Age} = 41)\).

Duration of O&M training \((\text{at least weekly instruction excluding summer and winter breaks})\) varied from 1 month to 18 years \((Mdn = 6 \text{ months})\) for the two-point touch preferred group, while it ranged from 1 month to 13 years \((Mdn = 4 \text{ months})\) for the constant contact preferred group. The experienced cane user group’s O&M training duration varied from 1 month to 18 years \((Mdn = 9 \text{ months})\), while that of the inexperienced group ranged from 1 month to 6 months \((Mdn = 2 \text{ months})\).
Main Effects

There was no statistically significant interaction between preferred cane technique and the type of cane technique used in drop-off detection trial (see Figure 2-2), $F(1, 30) = .052, p = .820$. Therefore, the main effects of these two factors have been examined (Keppel, 1991). As can be seen in Table 2-1, drop-off detection threshold of the constant contact technique ($M = 1.65"$, $SD = .93"$) was statistically significantly smaller (i.e., more sensitive) than that of the two-point touch technique ($M = 2.91"$, $SD = 1.14"$), $F(1, 30) = 68.240, p < .001$. The overall drop-off detection rate of the constant contact technique ($M = 78.3\%, SD = 14.1\%$) was also statistically significantly higher than that of the two-point touch technique ($M = 62.1\%, SD = 15.5\%$), $F(1, 30) = 68.240, p < .001$. Even for large drop-offs (5 and 7 inches), which, if missed, could pose a serious risk of falling, drop-off detection rate with the constant contact technique ($M = 97.7\%, SD = 8.9\%$) was statistically significantly higher than that with the two-point touch technique ($M = 92.0\%, SD = 15.0\%$), $F(1, 30) = 5.916, p = .021$. There was no statistically significant order effect of the cane technique on drop-off detection threshold, $F(1, 30) = 1.367, p = .252$, overall drop-off detection rate, $F(1, 30) = .414, p = .525$, or drop-off detection rate for large drop-offs, $F(1, 30) = .009, p = .924$.

The drop-off detection threshold of the participants whose preferred cane technique was the two-point touch ($M = 2.31"$, $SD = .97"$) was not statistically significantly different from that of those whose preferred cane technique was the constant contact ($M = 2.26"$, $SD = .94"$), $F(1, 30) = .021, p = .886$ (see Table 2-1). Similarly, the overall drop-off detection rate of the participants whose preferred cane technique was
two-point touch ($M = 71.6\%, SD = 12.7\%$) was not statistically significantly different from that of those whose preferred cane technique was constant contact ($M = 69.5\%, SD = 14.7\%$), $F(1, 30) = .160, p = .692$. 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 $M = 93.3\%, SD = 13.0\%$), $F(1, 27.2) = 1.177, p = .171$.

Given the significant interaction between the years of cane use and the type of cane technique used in drop-off detection (see Figure 2-3), $F(1, 30) = 20.025, p < .001$, simple effects rather than the main effects have been examined in the analysis of these
Table 2-1

*Effects of Preferred Cane Technique, Years of Cane Use, and the Type of Cane Technique Used on Drop-off Detection (N = 32)*

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>50% Detection Threshold (inches)</th>
<th>Overall Detection Rate (%)</th>
<th>Large Drop-off Detection Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>p</td>
</tr>
<tr>
<td>Cane Technique Used in Detection (Within-group)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC (n = 32)</td>
<td>1.65</td>
<td>.93</td>
<td></td>
</tr>
<tr>
<td>TT (n = 32)</td>
<td>2.91</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-1.26</td>
<td>.91&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Preferred Cane Technique (Between-groups)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC (n = 21)</td>
<td>2.26</td>
<td>.94</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TT (n = 11)</td>
<td>2.31</td>
<td>.97</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-0.05</td>
<td>.94</td>
<td>.886</td>
</tr>
<tr>
<td>Years of Cane Use (Between-groups)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2+ Years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 24)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC*</td>
<td>1.74</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>TT*</td>
<td>2.66</td>
<td>.97</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-.92</td>
<td>.68 &lt;.001</td>
<td></td>
</tr>
<tr>
<td>Less than 2 yrs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC*</td>
<td>1.40</td>
<td>.69</td>
<td></td>
</tr>
<tr>
<td>TT*</td>
<td>3.64</td>
<td>1.37</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-2.24</td>
<td>.84 &lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* No 3-way interaction was examined. CC = constant contact technique. TT = two-point touch technique.
*Cane technique used in drop-off detection. Given the absence of significant interaction between preferred cane technique and the type of cane technique used in drop-off detection, main effects of these variables were 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 were reported.*
two variables (Keppel, 1991). As can be seen in Table 2-1, for those who had used the cane for less than 2 years, the threshold of the constant contact technique ($M = 1.40''$, $SD = .69''$) was statistically significantly smaller than that of the two-point touch technique ($M = 3.64''$, $SD = 1.37''$), $F(1, 7) = 56.785, p < .001$. The constant contact technique’s advantage over the two-point touch technique was present for the more experienced group as well (constant contact $M = 1.74''$, $SD = 1.00''$; two-point touch $M = 2.66''$, $SD = .97''$, $F(1, 23) = 44.700, p < .001$), albeit by a much smaller degree.

Note. Error bars indicate 95% confidence intervals.

Figure 2-3. Interaction Between Years of Cane Use and Type of Cane Technique Used in Drop-off Detection Trial
Table 2-1 also shows that the detection rate for the large drop-offs with the constant contact technique \((M = 99.5\%, \ SD = 1.8\%)\) was statistically significantly higher than that with the two-point touch technique \((M = 96.6\%, \ SD = 6.6\%)\) for those who had used the cane for 2 or more years, \(F(1, 23) = 4.467, \ p = .046\). For less experienced cane users, the large drop-off detection rate with the constant contact technique \((M = 92.2\%, \ SD = 17.3\%)\) was not statistically significantly higher than that with the two-point touch technique \((M = 78.1\%, \ SD = 23.6\%)\), \(F(1, 7) = 5.108, \ p = .058\). However, as was the case in drop-off detection threshold, the difference in drop-off detection rate between the constant contact technique and the two-point touch technique for the less experienced cane users \((M = 14.1\%, \ SD = 17.6\%)\) was much larger than that for the experienced cane users \((M = 2.9\%, \ SD = 6.8\%)\).

Figure 2-4 shows an interaction contrast between the cane technique (when preferred cane technique was used in drop-off detection trial) and years of cane use. Caution is needed when interpreting this interaction because only one participant was categorized as a preferred two-point touch technique user with less than 2 years of experience. Among the experienced cane users, when the participants used their own preferred cane technique in drop-off detection, constant contact technique’s drop-off detection threshold \((M = 1.48\", \ SD = .71\")\) was smaller than that of the two-point touch technique \((M = 2.91\", \ SD = 1.06\")\). Similarly, among the less experienced cane users, when their own preferred cane technique was used in drop-off detection, the constant contact technique’s drop-off detection threshold \((M = 1.70\", \ SD = .94\")\) was smaller than that of the two-point touch technique \((M = 3.00\", \ SD = .00\")\). No noticeable interaction was observed.
In this study, 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 drop-off detection was significantly larger for the less experienced cane users than for the experienced ones.

*Note.* There was only one inexperienced participant (less than 2 years of cane use) whose preferred cane technique was the two-point touch.
Effect of Type of Cane Technique Used in Drop-off Detection

Participants detected drop-offs better when using the constant contact technique than when using the two-point touch technique. This was true regardless of what their preferred cane technique was. The advantage of the constant contact technique in drop-off detection threshold was 1.20 inches for those whose preferred cane technique was the two-point touch, and 1.28 inches for those whose preferred cane technique was the constant contact. It is particularly important to note that the difference in drop-off detection performance between the constant contact technique and the two-point touch technique was significant not only statistically but also clinically. For example, even for large drop-offs (5 and 7 inches), which, if missed, could pose a serious risk of falling, the participants still missed 1 in 12 drop-offs with the two-point touch technique, while they missed less than 1 in 40 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 length of inter-stimulus intervals. To detect drop-offs using the constant contact technique, a cane user needs to discriminate the two stimuli that are presented with no (or marginal in length) inter-stimulus interval, whereas to detect drop-offs using the two-point touch technique, he is required to compare the two stimuli with a longer inter-stimulus interval. That is, vibro-tactile feedback a cane user receives when using the constant contact technique—sweeping the cane side to side with his cane tip in constant contact with the walking surface—changes little during his approach to the drop-off. Then this steady baseline stimulus is instantly followed by an increased pressure on the cane holding hand when the
cane tip passes the drop-off edge and lands on the sunken surface. On the other hand, when the two-point touch technique—intermittent tapping on the walking surface—is used, the vibro-tactile feedback 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 vibro-tactile stimulus he received during his approach to the drop-off. 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 proprioceptive/kinesthetic and vibro-tactile senses (Gescheider, Bolanowski, Verrillo, Arpajian, & Ryan, 1990; Kaplan, Nixon, Reitz, Rindfleish, & Tucker, 1985; Wickelgren, 1966).

**Effect of Preferred Cane Technique**

We did not find a statistically significant difference in drop-off detection performance between the cane users who used the two-point touch as the preferred cane technique and those who used the constant contact as the primary cane technique. One of the possible explanations for such result is that regardless of which technique was used as the cane user’s preferred cane technique, the other technique may have been used often enough to develop and maintain the competency in both techniques. Another possible explanation can be found in the fact that the two-point-touch-technique-preferred group was statistically significantly older than the constant-contact-technique-preferred group with median ages of 48 and 30, respectively. Since age appears to affect drop-off detection performance negatively (Kim et al., in press), the two groups’ age difference could have masked a possible preferred cane technique effect. However, such masking
effect didn’t seem to be substantial given the insignificant main effect of the primary cane technique, $F(1, 18) = 1.998, p = .175$, even in the comparison made after trimming the younger participants from the constant contact group to equalize the two groups’ median age (two-point touch $Mdn = 48$ years; constant contact $Mdn = 47$ years).

**Interactions**

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

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

It has been noted that the amount of O&M training differed significantly between the participants who used the cane for 2 or more years ($Mdn = 9$ months) and the ones who were less experienced ($Mdn = 2$ months). Given the strong correlation between the years of cane use and years of O&M training ($r = .504$), as well as the fact that most O&M training sessions involve cane skill practice (either as an objective of the lesson or as a component needed to accomplish other objectives), it does not appear unreasonable to regard these two variables as measures of the same construct—cane technique practice. The effect of years of O&M training on drop-off detection threshold was similar to the effect of years of cane use, albeit with weaker interaction with the type of cane technique used in drop-off detection.

**Strengths and Limitations**

Order effect was controlled for by randomly assigning participants to one of the two conditions: two-point touch technique first or constant contact technique first. In respect 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 used in the experiment. Although this study was not designed to determine whether increased surface irregularities affects drop-off detection performance negatively, it is possible that such potentially negative effect of surface irregularities on drop-off detection is larger for
the constant contact technique than for the two-point touch technique given the constant contact technique's higher propensity to stick on rougher walking.

Another limitation of the study is related to the study sample. A small sample that was obtained through a nonprobability sampling method limits the generalizability of the study findings. In addition, despite the efforts to balance the groups in respect to important characteristics, such efforts were only partially successful. For example, although the experienced cane user group's age was similar to that of the inexperienced group, the median age difference between the two preferred cane technique groups was significant. However, the confounding effect of age was modest at most. Last, there was only one participant who was categorized as less experienced two-point touch technique user, which rendered the interpretation of the interaction between the years of cane use and preferred cane technique tenuous at best.

Implications

Many consumers who are visually impaired receive only a limited amount of O&M training primarily due to shortage of funding. Such occurrences are common, particularly for nonvocational-track older consumers who receive training from itinerant O&M specialists. Given the limited amount of authorized time for training, O&M specialists often need to prioritize what skills to teach during their limited training sessions. If such decisions need to be made in respect to cane training, particularly if detecting smaller drop-offs as well as larger ones is critical for the given consumer due to balance problems, O&M specialists may consider focusing their instructions on the constant contact technique rather than attempting to have the consumer develop equally
the abilities to reliably detect drop-offs with both the two-point touch and the constant contact techniques. However, we do not suggest that constant contact technique should be the primary cane technique taught to every long cane user. Rather, O&M specialists should assess the client’s abilities and situation as well as the merits and limitations of each technique when determining what technique should be used in a given situation.

Recommendations

Future studies may be needed to examine user characteristics that may affect drop-off detection performance, including cane users’ age and their age at onset of visual impairment. Investigation of how ergonomic factors and biomechanical factors (e.g., cane arc width, position of the cane holding hand) affect drop-off detection performance may also be useful. Furthermore, with sufficient sample size, analyses can be conducted to examine relationships between drop-off detection performance and specific predictor variables while controlling for the other variables in the model. Finally, it is necessary to examine multiple aspects of long cane performance, which include obstacle detection, texture discrimination, and travel efficiency, as well as drop-off detection, in order to determine the overall effectiveness of cane travel.

References


chapter III

Analysis of User Characteristics Related to Drop-off Detection with the Long Cane

Drop-off detection with the long cane, which appears to involve proprioceptive/kinesthetic and vibro-tactile perception (Chan & Turvey, 1991), is critical for blind cane users’ safe travel. It has been well documented that aging is associated with deterioration of perceptual sensitivities (Fozard & Gordon-Salant, 2001; Goble, Coxon, Wenderoth, Van Impe, & Swinnen, 2009; Verrillo, 1993). Many studies have also shown that there are sensitive (critical) periods for optimal development of perceptual abilities (Blakemore & Cooper, 1970; Crair, Gillespie, & Stryker, 1998; Hirsch & Spinelli, 1970; Rauschecker, 1999). Given such, age of blind travelers and their age at onset of visual impairment, as well as different types of cane techniques, may be related to a blind traveler’s ability to detect drop-offs with the long cane.

Most blind travelers rely on a long cane to detect obstacles and drop-offs on their walking paths (Hill & Ponder, 1976). The two-point touch technique—moving the cane from side to side and touching the edges of one’s walking path in an arc slightly wider than one’s shoulders—has been the standard long cane technique since its development during World War II (Hill & Ponder, 1976; Miller & Hoover, 1946). The constant contact technique—sweeping the cane from side to side in an arc slightly wider than one’s shoulders while keeping the cane tip in contact with the surface at all times (De Bruin, 1981)—has also been widely used by blind travelers in the past few decades. Although
these two techniques are similar in many aspects, the primary difference lies in the fact that the cane tip stays in constant contact with the walking surface, including while the cane is swung back and forth, when the constant contact technique is used, whereas the cane tip is lifted off the walking surface and swung to the opposite side between each tap on the surface when the two-point touch technique is used.

Regardless of which cane technique is used, it is crucial for blind travelers to reliably detect surface elevation changes, particularly drop-offs; a cane user may fall or accidentally put himself in the collision path of an oncoming vehicle by missing a curb while walking on a sidewalk (Uslan & Schriebman, 1980). Drop-off detection may become particularly important as a person ages since the consequences of falls are often serious among older individuals (Gillespie et al., 2009; Hayes et al., 1996; Lord, 2006). As many as 75% of older individuals who suffer fall-induced hip fractures do not fully recover their ambulatory and activities of daily living (ADL) functions (Magaziner, Simonsick, Kashner, Hebel, & Kenzora, 1990). Between 32% and 80% of older individuals who survive the hospitalization following a fall-induced hip fracture incur permanent disability (McClure et al., 2005). In addition, 15% of older individuals who experience hip fracture die in the hospital and more than 30% of survivors do not live beyond one year (Rose & Maffulli, 1999).

Age-related deterioration of perceptual sensitivities appears to be present across different perceptual modalities, including vision (Bennett, Sekuler, & Sekuler, 2007; Owsley, Sekuler, & Siemsen, 1983), hearing (Fitzgibbon & Gordon-Salant, 2001; Stevens, Cruz, Marks, & Lakatos, 1998), taste (Mojet, Christ-Hazelhof, & Heidema, 2001), and smell (Stevens & Dadarwala, 1993). Declines in proprioceptive/kinesthetic
(Pai, Rymer, Chang, & Sharma, 1997; Skinner, Barrack, & Cook, 1984) and vibro-tactile sensitivities (Gescheider, Edwards, Lackner, Bolanowski, & Verrillo, 1996; Stevens & Foulke, 1996) of older individuals have also been documented. In addition, aging negatively affects one’s balance (Baloh et al., 1994; Wolfson, 2001), and increases postural sway while walking (Miyata & Shirato, 1994). Such decline in balance and increase in body sway may augment the variability of motion-related parameters. This may negatively affect one’s ability to detect subtle changes in body position while walking with a long cane (e.g., changes in wrist and elbow angles of the cane-holding hand) since maintaining motion-related parameters relatively constant appears to help kinesthetic and vibro-tactile perception (Turvey & Carello, 1995).

We have not found any published experimental studies that examined the effect of age on drop-off detection. A preliminary study (Kim, Wall Emerson, & Curtis, in press) indicated a negative correlation between a participant’s age and drop-off detection performance, but the study was not designed to make inference in this regard to the corresponding population.

Age at onset of sensory loss, including vision loss, also appears to affect perceptual abilities because distinct sensitive (critical) periods that allow full development of perceptual abilities seem to exist (Blakemore & Cooper, 1970; Crair et al., 1998; Hirsch & Spinelli, 1970; Rauschecker, 1999). These sensitive periods seem to differ across sensory modalities (de Schonen, Mancini, Camps, Maes, & Laurent, 2005; Sathian, 2005). For example, sensitive period for stereoacuity seems to end at 36 months (Birch & Hale, 1989), while the highly plastic period for the development of central auditory system appears to close out at age seven (Sharma, Dorman, & Spahr, 2002).
Drever (1955) suggested that kinesthetic practice beyond the age of 4 does not significantly improve an individual's kinesthetic abilities, while Facchini and Aglioti (2003) reported a significant improvement in tactual discrimination of grating orientation after 90 minutes of practice by blindfolded sighted adults, suggesting a presence of effective vibro-tactile learning even in adulthood. Given the possibility of varying sensitive periods for kinesthetic/proprioceptive and vibro-tactile perceptual learning, it is important to compare drop-off detection performance between the cane users who have earlier-onset visual impairment and those who have later-onset impairment. A preliminary study (Kim et al., in press) showed that cane users with earlier-onset visual impairment detected drop-offs better than those with later-onset visual impairment; however, this was within the sample in which 10 of the 15 participants had later-onset impairment. We have not found any other published experimental design studies that investigated how the age at onset of visual impairment affects drop-off detection performance.

Albeit with variation (Goble et al., 2009), it appears that significant age-associated deterioration of proprioceptive/kinesthetic sensitivities occurs as early as one's 50s (Ferrell, Crighton, & Sturrock, 1992) and often by the 60s (Bullock-Saxton, Wong, & Hogan, 2001; Kaplan, Nixon, Reitz, Rindfleish, & Tucker, 1985; Petrella, Lattanzio, & Nelson, 1997). Deterioration of vibro-tactile sensitivities with aging appears to be somewhat less consistent. For example, sensitivities to certain low frequency vibro-tactile stimuli do not appear to deteriorate until one's 70s (Perry, 2006) or even early 80s (Wells, Ward, Chua, & Inglis, 2003). If the cane users rely more on proprioceptive/kinesthetic perception to detect drop-offs when using the two-point touch technique, while they rely
more on vibro-tactile perception to detect drop-offs when using the constant contact technique, differential deterioration of proprioceptive/kinesthetic and vibro-tactile sensitivities may indicate possible interaction between a cane user’s age and the type of cane technique used in drop-off detection. In addition, although anecdotal, some O&M specialists who work with both young and old consumers have reported that older cane users tend to detect drop-offs far better with the constant contact technique than with the two-point touch technique, while this difference is smaller for younger cane users (R. O. LaDuke, personal communication, February 4, 2009; M. J. Weessies, personal communication, February 4, 2009).

One of the primary purposes of this study was to examine how age affects drop-off detection performance. Another purpose of the study was to investigate how the age at onset of visual impairment affects drop-off detection. In addition, this study examined whether the following two specific interactions were present: (1) cane user’s age and the type of cane technique used in drop-off detection, and (2) age at onset of visual impairment and the type of cane technique used in drop-off detection.

Method

Study Design and Recruitment Criteria

This study used a mixed-measures design with block randomization, in which the participants used either the two-point touch technique or the constant contact technique to detect drop-offs of various depths. Legally blind adults with no other disabilities were eligible to participate. Participant selection criteria also included familiarity with both the
two-point touch and constant contact techniques as well as a minimum of 1-month-long cane training. Although not a requirement, efforts were made to acquire a balanced sample in respect to age, cane use experience, and preferred cane technique.

A total of 32 individuals participated in the study; 15 of them participated in 2008 (Kim et al., in press), while the remaining 17 participated in 2009. Given the identical recruitment criteria and experimental protocol during both periods, the data from the previous 15 participants were combined with those from the newly recruited 17 for the analysis.

Apparatus

Six carpeted platforms (8 feet long, 4 feet wide, 8 inches high) were used to form a 32-foot-long walkway (see Figure 3-1). The walkway was 4 feet wide for the first half and 8 feet wide for the latter half that led to the drop-off. The drop-off depth was varied using two plywood boards (2 feet long, 4 feet wide) that were placed on top of braced rectangular wooden frames (2 feet long, 4 feet wide, 2 inches high). Carpeting on the plywood boards was identical to the carpeting on the walkway, which was intended to prevent the participants from using tactile and auditory feedback for detecting drop-offs. Identical long canes (Ambutech UltraLite Graphite Rigid Cane) of different lengths were used for all participants. All canes were equipped with identical cane tips (Ambutech MT4080 High Mileage Tip). The length of the cane used by each participant was determined based on height following the guideline outlined in LaGrow and Weessies (1994): each participant was given a cane that was as long as the vertical distance from
the ground to 2 inches above the participant's xiphoid process. All trials were videotaped using a digital camcorder (Panasonic SDR-S10P1).

Figure 3-1. Participant Approaching the Drop-off on the 32-Foot-Long Walkway Used in the Study

Research Procedure

Western Michigan University's (WMU) College of Health and Human Services building basement hallway was used for all experiments. Each participant, upon arrival at the site, signed an informed consent form approved by WMU's Human Subjects Institutional Review Board. Through verbal briefing and two practice trials, participants learned about the test site and experiment procedure. Participants wore sleep-shades and a full-size headphone set (RadioShack Full-Size Stereo Headphone 33-1225) connected to an MP3 player (i-Pod Generation 5) during all trials, from which they heard rhythmic
beats (90–110 beats per minute) over a white noise background (recorded by Sound for Life). The experimenter (a Certified Orientation and Mobility Specialist) set the speed of the rhythmic beats based on the participant's comfortable stepping speed, then the participant was instructed to synchronize their steps to the beats during all trials. Such instruction was intended to help the participant walk at a consistent pace throughout the trials, limiting the potential confounding effect of walking speed on drop-off detection.

Each participant was positioned at the center of the walkway, squarely facing the drop-off. Randomly selected starting points (between 14 and 30 feet) were used for different trials to prevent the participants from predicting the distance to the drop-off. Upon receiving a signal from the experimenter, the participant approached the drop-off using either the two-point touch or the constant contact technique. Participants stopped immediately upon detecting the drop-off and verbally indicated the detection of the drop-off. The experimenter followed the participant closely and helped him if he stumbled off the walkway. The experimenter guided the participant to the next starting point upon completion of each trial, using a zigzag pattern to prevent the participant from knowing the distance to the drop-off.

Sixty-four trials were completed for each participant: eight trials for each drop-off depth (1", 3", 5", 7") for each cane technique (two-point touch, constant contact). We randomly assigned participants to either the two-point touch technique first condition or the constant contact technique first condition to control for possible order effects. Height of the plywood boards placed against the walkway was changed from trial to trial based on block randomization method.
A trial was recorded as a miss if the participant fell off the drop-off or would have fallen off the drop-off had it not been for the intervention of the experimenter. It was necessary for the experimenter to intervene at times to prevent injuries, particularly when larger drop-offs were presented. Interrater reliability was 98% in a preliminary study (Kim et al., in press).

Variables

Drop-off detection performance (dependent variables) was measured by 50% absolute drop-off detection threshold, overall drop-off detection rate, and large drop-off detection rate. Psychometric function described in Gescheider (1997, pp. 45-48) was used to calculate the 50% absolute drop-off detection threshold for each technique. That is, a cumulative normal distribution curve was fitted to the data points to estimate the drop-off depth that was detected in 50% of the trials. Overall drop-off detection rate was computed by dividing the total number of detections by total number of trials. Large drop-off detection rate was calculated in a similar manner, but only with 5- and 7-inch drop-off detection rates combined.

Independent variables of the study included cane user's age (between-groups variable with two categories: 50 or younger, older than 50), age at onset of visual impairment (between-groups variable with two categories: 4 or younger, older than 4), and the type of the cane technique used in drop-off detection trial (within-group variable with two categories: two-point touch, constant contact). The effect of the type of cane technique used in drop-off detection was examined only as it interacted with the other
two variables since its main effect had been investigated in a previous study (Kim et al., in press).

**Analysis**

Upon completing a series of preliminary descriptive statistical procedures, we used a two-way mixed-measures Analysis of Variance (ANOVA) to examine the main effects and interaction effects of independent variables on drop-off detection performance; the three-way interaction was not examined in this study given its limited interpretability and practical benefits. Simple effects, rather than main effects, have been examined in the presence of significant interaction between the factors.

We specifically tested the two-way interaction between the age of the cane user (between-groups factor) and the type of cane technique used in drop-off detection (within-group variable), as well as the two-way interaction between the age at onset of visual impairment (between-groups factor) and the type of cane technique used in drop-off detection (within-group variable). The interaction between cane user’s age and age at onset of visual impairment was examined purely descriptively with no corresponding hypothesis due to limited statistical power. Medians were used as measures of central tendency when there was a significant deviation from normal distribution, while the Welch (1951) procedure was used to control for the probability of a type I error when the homogeneity of variance assumption was violated.

We used a significance level of .05 for all statistical tests (two-tailed) in this study. The statistical power was at least .52 for main effect and interaction effect tests when a large effect size \( f = .4 \) was assumed (Cohen, 1988; Erdfelder, Faul, & Buchner,
1996). G*Power version 3.0.10 was used for statistical power analyses, while SPSS version 16.0 was used for all other analyses.

Results

Participant Demographics

Participants’ (18 males, 14 females) visual acuities ranged from no light perception to 20/200. Causes of vision loss 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 ($n = 14$). Median age of the earlier-onset visual impairment group was 28.5 (range = 20 to 66), while that of the later-onset visual impairment group was 41 (range = 22 to 75). Years of cane use varied from 1 month to 42 years ($Mdn = 9$ years) for the younger cane user group, while it ranged from 1 month to 29 years ($Mdn = 7$ years) for the older cane user group. Earlier-onset visual impairment group’s cane use experience spanned from 3 years to 42 years ($Mdn = 18$ years), while that of the later onset visual impairment group ranged from 1 month to 36 years ($Mdn = 5$ years).

Main Effects

There was no statistically significant interaction between cane user’s age and the type of cane technique used in drop-off detection trial (see Figure 3-2), $F(1, 30) = .001$, $p = .896$; therefore, the main effect of cane user’s age was analyzed. The drop-off detection threshold of the younger participants ($M = 2.05"$, $SD = .84"$) was statistically
significantly smaller than that of the older participants ($M = 3.10''$, $SD = .87''$), $F(1, 30) = 8.505, p = .007$ (see Table 3-1). Similarly, the overall drop-off detection rate of the younger cane users ($M = 72.8\%, SD = 13.7\%$) was statistically significantly higher than that of those who were older ($M = 60.9\%, SD = 10.8\%$), $F(1, 30) = 4.436, p = .044$.

![Type of Cane Technique Used in Drop-off Detection](image)

**Figure 3-2.** Effects of Cane User's Age (Between-Groups) and Type of Cane Technique Used (Within-Group) on Drop-off Detection Threshold

*Note.* Error bars indicate 95% confidence intervals.

There was no statistically significant interaction between age at onset of visual impairment and the type of cane technique used in drop-off detection trial (see Figure 3-3), $F(1, 30) = .647, p = .428$. Given such, the main effect of the age at onset of visual impairment was examined. The drop-off detection threshold of the participants who lost their vision at age 4 or younger ($M = 1.78''$, $SD = .67''$) was statistically significantly
Table 3-1

*Main Effects of Cane User's Age and Age at Onset of Visual Impairment on Drop-off Detection (N = 32)*

<table>
<thead>
<tr>
<th></th>
<th>50% Detection Threshold</th>
<th>Overall Detection Rate</th>
<th>Large Drop-off Detection Rate*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (inches)</td>
<td>SD (inches)</td>
<td>p</td>
</tr>
<tr>
<td><strong>Age of Cane User</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 or Younger (n = 25)</td>
<td>2.05</td>
<td>.84</td>
<td>.007</td>
</tr>
<tr>
<td>Older than 50 (n = 7)</td>
<td>3.10</td>
<td>.87</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>−1.05</td>
<td>.84</td>
<td></td>
</tr>
<tr>
<td><strong>Onset of Visual Impairment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 or Younger (n = 12)</td>
<td>1.78</td>
<td>.67</td>
<td>.018</td>
</tr>
<tr>
<td>Older than 4 (n = 20)</td>
<td>2.58</td>
<td>.96</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>−.80</td>
<td>.87</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Results on the effect of type of cane technique used on drop-off detection performance were reported in a previous study (Kim et al., in press).*

Detection rate for 5 and 7 inch drop-offs. bThere was a significant interaction between cane user’s age and the type of cane technique used in drop-off detection for large drop-off detection rate. As a result, the main effect of cane user’s age on large drop-off detection rate reported in this table should be interpreted with caution. Simple effects in this regard have been reported in the text and Figure 3-5.
smaller than that of those with later-onset visual impairment ($M = 2.58''$, $SD = .96''$), $F(1, 30) = 6.307$, $p = .018$ (see Table 3-1). Similarly, the overall drop-off detection rate of the earlier-onset group ($M = 78.0\%, SD = 9.0\%$) was statistically significantly higher than that of the later-onset group ($M = 65.5\%, SD = 14.4\%$), $F(1, 30) = 7.227$, $p = .012$. In addition, the drop-off detection rate for large drop-offs (5 and 7 inches) was statistically significantly higher for the earlier-onset group $M = 99.7\%, SD = .9\%$) than for the later-onset group ($M = 91.9\%, SD = 13.1\%$), $F(1, 19.3) = 7.132$, $p = .015$.

As mentioned earlier, in respect to drop-off detection threshold and overall drop-off detection rate, we did not obtain a statistically significant interaction between cane user's
age and the type of cane technique used in drop-off detection trial. However, we found a statistically significant interaction between these two variables for large drop-off detection rate (see Figure 3-4), $F(1, 30) = 7.791, p = .009$. Given such, simple effects have been examined in the analysis of these two variables in respect to large drop-off detection rate (Keppel, 1991). For those who were 50 or younger, large drop-off detection rate with the constant contact technique ($M = 97.2\%, SD = 10.1\%$) was statistically significantly higher than that with the two-point touch technique ($M = 94.2\%, SD = 12.9\%$), $F(1, 24) = 4.571, p = .043$. The constant contact technique’s advantage over the two-point touch technique was larger for older cane users (constant contact $M = 99.1\%$,

![Figure 3-4](image)

*Note.* Error bars indicate 95% confidence intervals.

**Figure 3-4.** Interaction Effect of Cane User’s Age (Between-Groups) and Type of Cane Technique Used in Drop-off Detection Trial (Within-Group) on Large Drop-off Detection Rate
$SD = 2.4\%; \text{two-point touch } M = 83.9\%, SD = 20.0\%$, although this difference was not statistically significant, $F(1, 6) = 4.983, p = .067$, perhaps due to lower statistical power.

The interaction between cane user’s age and the age at onset of visual impairment was examined purely descriptively due to limited statistical power (see Figure 3-5). Added caution is needed when interpreting this result because there was only one participant who was older and had earlier-onset visual impairment. Drop-off detection performance gap between the earlier-onset and later-onset visual impairment groups was larger among the older cane users ($M = 1.23''$, $SD = .81''$) than among the younger ones ($M = .52''$, $SD = .80''$).

![Figure 3-5. Interaction Between Cane User’s Age and Age at Onset of Visual Impairment Effect of Cane User’s Age](image-url)
Discussion

There was no interaction between examined user characteristics (age, age at onset of visual impairment) and the type of cane technique used in drop-off detection. However, this study found that younger cane users’ drop-off detection performance was significantly better than that of the older cane users. This study also found that the cane users with earlier-onset visual impairment were significantly better than those with later-onset visual impairment in drop-off detection.

Younger cane users detected drop-offs better than older cane users, which is consistent with the literature on how age is associated with proprioceptive/kinesthetic and vibro-tactile perceptual abilities (Gescheider et al., 1996; Pai et al., 1997; Skinner et al., 1984; Stevens & Foulke, 1996), as well as the result of a preliminary study result (Kim et al., in press). Decrease in the number of proprioceptors—muscle spindles that encode the limb’s position and its rate of change—seems to be one of the key underlying biological changes related to age-associated decline in proprioceptive sensitivities (Liu, Eriksson, Thornell, & Pedrosa-Domellof, 2005). Similarly, reduced density of Pacinian corpuscles with aging appears to be responsible for the decline in vibro-tactile sensitivities of older adults (Gescheider et al., 1996).

It was interesting that, in respect to smaller drop-off detection rate, younger cane users’ advantage over the older cane users was consistent regardless of which cane technique was used, while such advantage was much larger for the two-point touch technique than for the constant contact technique in large drop-off detection. Put another way, the advantage of the constant contact technique over the two-point touch technique
was substantially larger for the older cane users than for the younger cane users when the participants tried to detect larger drop-offs, but this advantage was consistent across age groups when they attempted to detect smaller drop-offs. Although it is possible that there exists a mechanism that caused such interaction, we are hesitant to rely on this result for further inference, primarily because this interaction was created not by further age-associated performance deterioration related to the two-point touch technique use, but by the improvement in performance with aging, albeit slight, in the constant contact technique use. Relatively small number of older participants \((n = 7)\) in the sample might have contributed to this apparently counter-intuitive result.

*Effect of Age at Onset of Visual Impairment*

Participants with earlier-onset visual impairment detected drop-offs better than those with later-onset visual impairment. One of the possible explanations for such a result may be that although the perceptual sensitivities required for drop-off detection can be learned in adulthood, they can be optimally developed earlier in life, particularly in the absence (or limited amount) of visual input. Given the presence of early-in-life sensitive periods in more thoroughly examined senses (e.g., vision, hearing), it is not unreasonable to suspect the existence of similar sensitive periods for proprioceptive/kinesthetic and vibro-tactile senses. However, the literature on this topic appears too sparse to support this hypothesis (Drever, 1955; Facchini & Aglioti, 2003).

Another possible explanation of age at onset of visual impairment’s significant effect on drop-off detection may be found in the age difference between the earlier-onset and later-onset visual impairment groups, with median ages of 28.5 and 41, respectively.
However, even when the older participants were trimmed from the later-onset visual impairment group to equalize the two groups in respect to age (earlier-onset group $M = 34.0$ years, $Mdn = 28.5$, range = 20 to 66; later-onset group $M = 33.7$ years, $Mdn = 33$, range = 22 to 47), the effect of age at onset of visual impairment was only slightly reduced (earlier-onset group threshold = 1.78", later-onset group threshold = 2.41").

It is also possible that the apparent effect of age at onset of visual impairment on drop-off detection resulted from the difference in years of cane use between the two groups. When the participants with shorter cane use experience were trimmed from the later-onset visual impairment group in an attempt to equalize the two groups in respect to years of cane use (earlier-onset group $M = 19.9$ years, $Mdn = 18$, range = 3 to 42; later-onset group $M = 18.5$ years, $Mdn = 15.5$ years, range = 10 to 36), the effect of age at onset of visual impairment was reduced more than marginally (earlier-onset group threshold = 1.78", later-onset group threshold = 2.21"), indicating the presence of possible confounding by the cane use experience.

**Strengths and Limitations**

Order effect was controlled for by randomly assigning participants to either the two-point touch technique first or the constant contact technique first condition. The study design also allowed each participant to serve as his or her own control when the simple effects of the within-group variable (type of cane technique used in drop-off detection) were examined.

Despite the attempts to acquire a sample that was balanced in important characteristics, such efforts were not entirely successful. Although the years of cane use
was similar between the younger and older cane user groups, there was a substantial difference in the years of cane use between the earlier-onset and later-onset visual impairment groups. In addition, there was only one participant who was categorized as an older cane user with earlier-onset visual impairment, which rendered the interpretation of the interaction between cane user’s age and age at onset of visual impairment tenuous at best.

Implications

Considering the increased frequency of falls with aging (Gillespie et al., 2009), particularly among the visually impaired older adults (Lord, 2006), coupled with often serious consequences of falls by those who are older (Magaziner et al., 1990), it is critical for O&M specialists to employ instructional strategies that would minimize the risk of falls by older cane users. While it is true that the constant contact technique’s advantage over the two-point touch technique in drop-off detection was similar for both younger and older individuals, if a drop-off is missed, older cane users may be more prone to falls than younger ones due to the decline in balance and reaction time (Patla et al., 1993). Given such, O&M specialists may consider recommending the constant contact technique in anticipation of drop-offs or other substantial surface depressions, particularly if the cane user is older or has a poor balance. Nevertheless, we do not claim that the constant contact technique is the only technique to be taught and recommended to every long cane user. Instead, cane user’s age, physical abilities, and other situations need to be evaluated, along with the merits and limitations of each technique, for appropriate cane technique selection.
**Recommendations**

Future cane studies may include examination of how biomechanical factors such as cane arc width and the position of the cane-holding hand affect drop-off detection performance. Investigation of how ergonomic factors (e.g., cane tips, cane length) affect drop-off detection may also have important practical implications. In addition, we may be able to utilize analysis techniques that allow us to examine the relationships between the predictor and outcome variables while controlling for the other variables in the model if we obtain a sample that is sufficient in size. Furthermore, in order to measure overall effectiveness of cane travel, various aspects of long cane performance, including obstacle detection, texture discrimination, and travel efficiency, need to be investigated.

**References**


CHAPTER IV

ANALYSIS OF ERGONOMIC FACTORS RELATED TO DROP-OFF DETECTION WITH THE LONG CANE

The use of a stick, staff, or a cane by persons who are blind for their independent travel has been documented since ancient times (Hoover, 1962). However, modern long cane design did not emerge until World War II when Dr. Hoover developed the systematic long cane techniques at Valley Forge General Hospital (Hoover, 1962). Type of cane tip, as well as the type of cane technique (Kim, Wall Emerson, & Curtis, in press), may affect how well a cane user can detect drop-offs.

The importance of cane tips stems from the fact that it is the part of a long cane that makes contact with the walking surface (Veterans Administration, 1964). Frequent sticking of the cane on the walking surface associated with certain types of cane tips (Lillie, 1987; Pietrowicz, 1987; Rodgers, 1991) may not only inconvenience the cane user but also affect the travel rate and consequently compromise the judgment on traveled distance (LaGrow, Kjeldstad, & Lewandowski, 1988).

Drop-off detection is one of the key functions of a long cane; missing a drop-off may result in falls or collision with moving vehicles in the street. Failure to detect a chuckhole or depressed slab on the sidewalk may also result in falls and consequent fall-induced injuries, which might cause serious fracture-related complications, particularly for older adults (McClure et al., 2005; Rose & Maffulli, 1999).
When examining the effect of different cane tips on drop-off detection performance, it is important to investigate such an effect in conjunction with the type of cane technique used in drop-off detection. This is because many cane tips have been designed to be used with specific cane techniques, and the cane techniques have a significant effect on drop-off detection performance (Kim et al., in press). Two primary cane techniques that are most commonly used by blind travelers are the two-point touch technique—swinging the cane side to side, tapping either side in an arc approximately 2 inches wider than the widest part of the body (Hill & Ponder, 1976; LaGrow & Weessies, 1994; Miller & Hoover, 1946)—and the constant contact technique—sweeping the cane side to side keeping the cane tip in constant contact with the walking surface in an arc slightly wider than the widest part of one’s body (De Bruin, 1981). Kim et al. (in press) suggested that the constant contact technique has a significant advantage over the two-point touch technique in detecting drop-offs.

Despite the importance of cane tips, only a small number of experimentally designed studies have examined how cane tips and other ergonomic factors affect cane performance. Rodgers and Wall Emerson (2005a) found that a cane shaft that is less flexible and lighter tends to help surface texture discrimination. Rodgers and Wall Emerson (2005b) also suggested that weight distribution of a cane does not affect texture discrimination, while a cane length that extends from the floor to 1.5 inches above the cane user’s xiphoid process is optimal for drop-off detection.

In a single-subject study in which he performed all tasks as the sole participant, Rodgers (1991) reported that the standard (pencil) tip caused the most incidences of sticking, which was followed, in decreasing order of sticking, by marshmallow, scallop,
metal glide, and curved tips. A few unpublished studies have also investigated the effects of different cane tips on frequency of sticking. Pietrowicz (1987) and Robertson (1987) found significantly fewer instances of sticking when using the marshmallow tip compared to when using the pencil tip on a rural road and residential sidewalk, respectively. Wang (1991) found the ball tip to be superior to the marshmallow or metal glide tip in reducing the frequency of sticking in a rural area, while Lillie (1987) found significantly less sticking when a marshmallow roller tip was used than when a marshmallow tip was used in a semi-business environment. However, LaGrow et al. (1988) found no significant difference in the frequency of sticking between the pencil, marshmallow, and curved tips. Yet, it should be noted that the participants in the Robertson (1987), Wang (1991), and Lillie (1987) studies used the constant contact technique, while those in the LaGrow et al. (1988) study used the two-point touch technique. Given the reported tendency of the two-point touch technique to stick less frequently than the constant contact technique (Fisk, 1986), the discrepancy between the findings of LaGrow et al. (1988) and the others may be at least partly a result of the use of different cane techniques.

Only one published experimental design study examined the effect of cane tips on drop-off detection. LaGrow et al. (1988) found no statistically significant difference in drop-off detection rate between the pencil, marshmallow, and curved tips; however, the participants in LaGrow et al. study used only the two-point touch technique for all drop-off detection trials.

Original specifications of a cane tip included a requirement that it be opaque white nylon or nylatron rod (or an equivalent) that is cylindrical in shape with the dimensions of 3½ inches in length and .5 inches in diameter (Veterans Administration,
1964). A National Academy of Sciences (1972) report on long canes emphasized the need for a cane tip to minimize friction and transmit vibrations in a way that would provide optimum tactile feedback. However, this report maintained the dimensional specifications of the cane tip originally described by the Veterans Administration (National Academy of Sciences, 1972). Despite little change in official specifications of a cane tip, various cane tips seem to have emerged in the late 1970s and 80s, partly in an effort to reduce sticking. These tips include wheeled, metal glide (Farmer, 1980), marshmallow, curved, pear-shaped (LaGrow et al., 1988), and scallop-shell-shaped tips (Rodgers, 1991).

Currently, more than a dozen different types of cane tips with various dimensions and materials are commercially available. However, they tend to fall into the following five categories: standard (pencil), marshmallow (teardrop), ball, roller, and metal (or ceramic) glide. In a survey conducted with 98 cane users in 2005, marshmallow tip was rated as the most preferred cane tip in 3 of 6 functional categories, which include durability, resiliency, and strength (Ambrose-Zaken, 2005). Although roller tips were not rated high in this survey, personal communications with one of the major cane tip vendors (T. Russell, personal communication, September 23, 2008) and O&M specialists (A. Kaufman, personal communication, February 2, 2009; M. J. Wcessies, personal communication, February 4, 2009; S. Williams-Riseng, personal communication, February 5, 2009) indicated its popularity is growing in recent years.

One of the obstacles to wider-spread use of the constant contact technique has been its propensity to sticking on walking surfaces (Fisk, 1986). Some of the cane users who preferred the constant contact technique in light of its ability to more reliably detect drop-offs (Kim et al., in press) started using the constant contact technique with a roller
tip to lesson the frequency of sticking (R. Saccoia, personal communication, March 30, 2008; S. Williams-Riseng, personal communication, January 31, 2009). Although roller tips appear to have ameliorated the sticking problem (Lillie, 1987), some cane users have stated that the use of a roller tip somewhat compromised their ability to detect drop-offs (D. Davis, personal communication, April 5, 2008; M. McCubbin, personal communication, March 16, 2008). Given such, one of the logical next steps is to examine whether the constant contact technique’s advantage over the two-point touch technique in drop-off detection (Kim et al., in press) can be maintained even when the constant contact technique is used with a tip that has a perceived disadvantage in drop-off detection (e.g., roller tip) while the two-point touch technique is used with a tip that is perceived to be more advantageous in detecting drop-offs (e.g., marshmallow).

Given the constant contact technique’s advantage over the two-point touch technique in drop-off detection when both techniques were used with the marshmallow tip, coupled with the fact that the two-point touch technique is rarely used with roller tips due to their heavier weight, this study aimed to investigate whether there is a difference in drop-off detection performance between the marshmallow and marshmallow roller tips when the constant contact technique is used with both tips. The other purpose of the study was to compare drop-off detection performance between the following two conditions: (1) two-point touch technique used with a tip perceived to be more advantageous for drop-off detection (marshmallow), and (2) constant contact technique used with a tip perceived to be less advantageous for drop-off detection (marshmallow roller).
Method

Study Design and Recruitment Criteria

This study was conducted in 2009 as part of a larger study on factors related to drop-off detection. A repeated-measures design with block randomization was used for the study. Seventeen adults who were legally blind and had no other disabilities were recruited. At least 1 month of cane training as well as familiarity and present use of both two-point touch and constant contact techniques was also required.

Apparatus

A 32-foot-long walkway with six carpeted plywood platforms (8 feet long, 4 feet wide, 8 inches high) was used for the study. The walkway was 4 feet wide for the first 16 feet and 8 feet wide for the latter 16 feet. We placed two plywood boards (2 feet long, 4 feet wide) laid on top of braced rectangular frames (2 feet long, 4 feet wide, 2 inches high) against the lengthwise end of the walkway to vary the drop-off depth from trial to trial. We used carpeting on the plywood boards that is identical to that on the walkway to prevent the participants from using tactile and/or auditory cues for drop-off detection.

Identical canes (Ambutech UltraLite Graphite Rigid Cane) were used for all trials. Definition of proper cane length outlined in LaGrow and Weessies (1994)—vertical distance from the ground to 2 inches above the cane user’s xiphoid process—was used to determine the cane length for each participant. Marshmallow roller tip (Ambutech MT4090 Marshmallow Roller Tip; 4.6 mm in length, 3.2 mm in diameter, 40g) and the marshmallow tip (Ambutech MT4080 High Mileage Tip; 3.5 mm in length, 2.5 mm in
diameter, 16g) were used in this study (see Figure 4-1). Each trial was recorded with a digital camcorder (Panasonic SDR-S10P1). Further details of the apparatus and research procedure are available in Kim et al. (in press).

![Figure 4-1. Marshmallow Tip (left) and Marshmallow Roller Tip (right) Experimental Procedure](image_url)

All experiments were conducted in an 8-foot-wide concrete hallway in Western Michigan University's College of Health and Human Services building basement (see Figure 4-2). 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 trials. Through the headphone set, participants heard rhythmic beats (90–110 beats per minute) over a white noise background (recorded by Sound for Life). The experimenter (a Certified Orientation and Mobility Specialist) set
the speed of the rhythmic beats per each participant's relaxed stepping speed and instructed the participant to synchronize his steps to the beats. Such instruction was designed to help the participant walk at an unchanging pace throughout the trials, limiting the potential confounding effect of walking speed on drop-off detection performance.

Figure 4-2. Participant Approaching the Drop-off on the 32-Foot-Long Walkway

We varied the starting points randomly (14 to 30 feet from the drop-off) from trial to trial to prevent the participants from estimating the distance to the drop-off. Participants walked towards the drop-off using either the two-point touch technique or the constant contact technique upon a tap on the shoulder by the experimenter. Participants stopped instantly upon detecting the drop-off and said “drop-off.” When a participant failed to detect the drop-off, the experimenter, if needed, intervened to keep the participant from tumbling off the drop-off.
Each participant completed eight trials for each drop-off depth (1", 3", 5", 7") for the following three conditions: (1) constant contact technique used with a marshmallow tip, (2) constant contact technique used with a marshmallow roller tip, and (3) two-point touch technique used with a marshmallow tip. That is, each participant completed a total of 96 trials. We used the block randomization method to vary the drop-off depth from trial to trial. We also used a Latin Square design to control for possible order effects. We recorded a trial as a miss if the participant fell off the drop-off or would have fallen off the drop-off had it not been for the experimenter's intervention. Interrater reliability was 98% in a preliminary study (Kim et al., in press).

**Variables**

Absolute drop-off detection threshold (50%) and drop-off detection rates were used as the measures of drop-off detection performance (dependent variables). We calculated the 50% absolute drop-off detection threshold for each of the three conditions stated above using the psychometric function outlined in Gescheider (1997, pp. 45-48). That is, a normal cumulative distribution curve was fitted to the data points for extrapolating the drop-off depth detected 50% of the time (threshold). Drop-off detection rates were computed by dividing the total number of detections by total number of trials for each drop-off depth (1", 3", 5", 7").

Type of the cane tip used in drop-off detection trial, which is a within-group variable with two categories (marshmallow, marshmallow roller), and the type of cane technique used in drop-off detection trial, which is also a within-group variable with two
categories (two-point touch, constant contact), were the independent variables of the study.

Analysis

Upon completion of descriptive statistical procedures, within-subjects $t$ tests were used to determine whether drop-offs could be better detected with the marshmallow tip than with the marshmallow roller tip when both tips were used with the constant contact technique. We also used within-subjects $t$ tests to determine whether the drop-offs could be better detected when the constant contact technique was combined with the marshmallow roller tip than when the two-point touch technique was combined with the marshmallow tip. Wilcoxon signed-ranks tests were used when the assumption of normality was violated. We used a significance level of .05 for all statistical tests (two-tailed). 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, except for power analyses (G*Power version 3.0.10), were conducted with SPSS version 16.0.

Results

Participant Demographics

Nine female and eight male adults who were visually impaired participated in the study. Visual acuities ranged from 20/200 to no light perception. Causes of visual impairment included retinopathy of prematurity ($n = 3$), diabetic retinopathy ($n = 2$), retinitis pigmentosa ($n = 2$), microphthalmia ($n = 2$), and others ($n = 8$). Visual
impairment occurred at age 4 or younger for seven participants, while it occurred beyond age 4 for the remainder. Participants' preferred cane tip included metal glide \((n = 8)\), marshmallow roller \((n = 4)\), pencil \((n = 3)\), marshmallow \((n = 1)\), and ball roller \((n = 1)\).

Participants' age varied from 23 to 75 \((Mdn = 37)\). Nine participants used the two-point touch technique more frequently \((60-90\% \text{ of the time}, Mdn = 75\%)\), while the others used the constant contact technique more often \((60-90\%, Mdn = 75\%)\).

Participants' years of cane use varied from 1 to 42 years \((Mdn = 22 \text{ years})\) for the two-point-touch-technique-preferred group, and 2 months to 13 years \((Mdn = 4 \text{ years})\) for the constant-contact-technique-preferred group.

Comparison of Marshmallow and Marshmallow Roller Tips

As shown in Figure 4-3, there was no statistically significant difference in drop-off detection threshold between the marshmallow \((M = 1.83", SD = 1.03"\)) and marshmallow roller tips \((M = 1.69", SD = .90"\)) when both tips were used with the constant contact technique, \(t(16) = .871, p = .397\).

Figure 4-4 shows that the difference between the marshmallow \((M = 74.4\%, SD = 15.1\%)\) and marshmallow roller tips \((M = 76.7\%, SD = 13.6\%)\) was not statistically significant for the overall drop-off detection rate, either, \(t(16) = -1.007, p = .329\). Furthermore, the large drop-off (5 and 7 inches) detection rate was identical for the two cane tips \((M = 96.3\%, SD = 12.1\%)\).

Figure 4-5 shows that the drop-off detection threshold of the constant contact technique used with the marshmallow roller tip \((M = 1.69"", SD = .90""
\)) was statistically significantly smaller than that of the two-point touch technique used with the
Figure 4-3. 50% Absolute Drop-off Detection Thresholds of Two Cane Tips When Both Tips Were Used with Constant Contact Technique

Figure 4-4. Drop-off Detection Rates by Type of Cane Tip Used When Both Tips Were Used with Constant Contact Technique
marshmallow tip ($M = 2.91''$, $SD = 1.02''$), $t(16) = 6.300, p < .001$. In other words, participants could detect much smaller drop-offs when using the constant contact technique with the marshmallow roller tip than when using the two-point touch technique with the marshmallow tip.

![Chart showing drop-off detection thresholds](chart.png)

**Note.** Error bars indicate 95% confidence intervals.

**Figure 4-5.** 50% Absolute Drop-off Detection Thresholds of Two Cane Techniques When Equipped with Different Cane Tips

The overall drop-off detection rate of the constant contact technique used with the marshmallow roller tip ($M = 76.7\%, SD = 13.6\%$) was statistically significantly higher than that of the two-point touch technique used with the marshmallow tip ($M = 61.8\%, SD = 15.4\%$), $z = -3.432, p = .001$. Drop-off detection rate difference between these two conditions gradually decreased as the drop-off depth increased, albeit with an exception
of 3" drop-off detection rate (see Figure 4-6). For large drop-offs, which, if missed, may pose a serious risk of falling, the drop-off detection rate difference between the constant contact technique used with the marshmallow roller tip ($M = 96.3\%, SD = 12.1\%$) and the two-point touch technique used with the marshmallow tip ($M = 93.8\%, SD = 14.0\%$) was not statistically significant, $z = -1.897, p = .058$. In other words, for large drop-offs, participants missed 1 in 16 drop-offs when they used the two-point touch technique with the marshmallow tip, while they missed 1 in 27 drop-offs when they used the constant contact technique with the marshmallow roller tip. This difference was larger for older cane users ($n = 4$), who did not miss any large drop-offs when they used the constant contact technique with the marshmallow roller tip, than for the younger ones ($n = 13$), who missed 1 in 13 large drop-offs when using the two-point touch technique with the marshmallow tip.

![Figure 4-6. Drop-off Detection Rates by Combinations of Type of Cane Technique and Type of Cane Tip](image-url)
Table 4-1 shows some of the characteristics of the participants as they relate to drop-off detection threshold. It is important to note that the result in Table 4-1 is a simple description of the sample data from which we made no inference to the population. The advantage of the constant contact technique (with marshmallow roller tip) over the two-point touch technique (with marshmallow tip) was consistent regardless of the participant’s preferred cane tip, difference in length between one’s own cane and the cane used in the experiment, as well as whether they travelled independently at least once a week. However, the advantage of the constant contact technique (with marshmallow roller tip) was much larger for the group with more functional vision ($M = 1.49", SD = .82")$ than for those with less ($M = .89", SD = .67")$.

Table 4-1

*Participant Characteristics in Relation to Drop-Off Detection Thresholds (inches)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Categories</th>
<th>TT&lt;sup&gt;a&lt;/sup&gt; with Marshmallow (A)</th>
<th>CC&lt;sup&gt;b&lt;/sup&gt; with Marshmallow Roller (B)</th>
<th>A - B N = 17 (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred Cane Tip</td>
<td>Marshmallow or pencil (n = 4)</td>
<td>2.65 (1.14)</td>
<td>1.39 (.86)</td>
<td>1.27 (.37)</td>
</tr>
<tr>
<td></td>
<td>Roller (n = 5)</td>
<td>2.85 (1.12)</td>
<td>1.60 (.88)</td>
<td>1.25 (1.10)</td>
</tr>
<tr>
<td></td>
<td>Metal glide (n = 8)</td>
<td>3.07 (1.01)</td>
<td>1.91 (.98)</td>
<td>1.16 (.82)</td>
</tr>
<tr>
<td>Cane Length Difference&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Under 6 inches (n = 10)</td>
<td>2.83 (1.06)</td>
<td>1.65 (1.06)</td>
<td>1.18 (.85)</td>
</tr>
<tr>
<td></td>
<td>6+ inches (n = 7)</td>
<td>3.01 (1.02)</td>
<td>1.76 (.68)</td>
<td>1.25 (.77)</td>
</tr>
<tr>
<td>Visual Acuity</td>
<td>NLP&lt;sup&gt;d&lt;/sup&gt;/LP&lt;sup&gt;e&lt;/sup&gt; (n = 8)</td>
<td>2.96 (1.12)</td>
<td>2.07 (1.06)</td>
<td>.89 (.67)</td>
</tr>
<tr>
<td></td>
<td>Better than LP (n = 9)</td>
<td>2.85 (.98)</td>
<td>1.36 (.60)</td>
<td>1.49 (.82)</td>
</tr>
<tr>
<td>Independent Travel&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Yes (n = 15)</td>
<td>2.86 (1.07)</td>
<td>1.67 (.93)</td>
<td>1.19 (.84)</td>
</tr>
<tr>
<td></td>
<td>No (n = 2)</td>
<td>3.27 (.38)</td>
<td>1.91 (.78)</td>
<td>1.36 (.39)</td>
</tr>
</tbody>
</table>

*Note.* <sup>a</sup>Two-point touch technique. <sup>b</sup>Constant contact technique. <sup>c</sup>Difference in length between the participant’s own cane and the cane he used in the study. <sup>d</sup>No light perception. <sup>e</sup>Light perception. <sup>f</sup>Traveled independently at least once a week.
Discussion

Drop-off detection performance was similar between the marshmallow and marshmallow roller tips when the constant contact technique was used for both cane tips. In addition, the constant contact technique used with a marshmallow roller tip (less advantageous tip) was more effective than the two-point touch technique used with a marshmallow tip (more advantageous tip) in detecting drop-offs.

The similarity between the marshmallow and marshmallow roller tips in drop-off detection performance when both tips were used with the constant contact technique is contrary to some of the cane users’ perceived advantage of the marshmallow tip over the marshmallow roller tip. One hypothesis that could be proposed to explain this result is that the difference in friction against the walking surface between the cane tips does not significantly affect drop-off detection performance. However, a counter argument could be made given the smooth carpeted walkway used in the study. In other words, it is possible that the experimental design of this study did not sufficiently allow a potentially important difference between the marshmallow and marshmallow roller tips—amount of friction against the walking surface—to affect drop-off detection performance. Differences in diameter and weight between the two cane tips could also have confounded the result. However, LaGrow et al. (1988) reported that there was no statistically significant difference in drop-off detection performance between the cane tips with different diameters. In addition, adding a moderate extra weight (up to 105 g) at the end of a rod did not appear to have affected the accuracy of vertical distance estimation (Chan & Turvey, 1991).
Constant contact technique was superior to two-point touch technique even when the former was used with a cane tip perceived to be disadvantageous for drop-off detection (marshmallow roller). The fact that older cane users did not miss any large drop-offs when they used the constant contact technique with the marshmallow roller tip, while they missed 1 in 14 drop-offs when they used the two-point touch technique with the marshmallow tip, suggests practical significance of the constant contact technique’s advantage over the two-point touch technique, particularly for those who are older.

Order effect was controlled for by the use of Latin Square design. In addition, the within-subject design allowed each participant to serve as his or her own control for potential confounding by variables such as age, experience, vision, preferred cane technique, and preferred cane tip. However, despite our efforts to include more older and less experienced cane users in our sample, only four participants who were older than 50, and three participants who had less than 2 years of cane use experience participated; this limits the generalizability of the findings to less experienced and older population. In addition, we only tested two of the many widely used cane tips in this study. Further, the smooth walking surface used in the study may not have adequately reflected the walking surface blind travelers encounter every day, which may include rough and uneven sidewalks as well as unpaved surfaces.

There are times O&M specialists recognize situations in which it would be more beneficial for the individual to use the constant contact technique than the two-point touch technique because of the need to detect drop-offs more reliably. Some cane users have shied away from using a roller tip (which appears to reduce the tendency to stick) in conjunction with the constant contact technique in fear of compromising their ability to
detect drop-offs. Given the findings of this study, O&M specialists may consider suggesting the constant contact technique with a marshmallow roller tip without the worry of compromised ability to detect drop-offs. However, the readers should not interpret the findings of this study as a suggestion to teach and use only the constant contact technique. Benefits and drawbacks of each cane technique, characteristics of the cane user (physical abilities, cane use experience), as well as the environment the person travels, need to be carefully evaluated before selecting a cane training strategy for an individual or an appropriate cane technique for a given environment.

Investigation of the cane tips other than the marshmallow and marshmallow roller tips may be needed given the variety of cane tips currently used by blind travelers. Exploring other ergonomic factors, including flexibility, length, and weight of the cane shaft, would also be important for fuller understanding of how ergonomic factors affect drop-off detection performance. In addition, testing the findings of this study in a more ecologically valid environment such as an actual sidewalk with surface irregularities would be necessary to test the practical applicability of the study findings.

References


National Academy of Sciences. (1972). *The cane as a mobility aid for the blind*. Report of a conference sponsored by the Committee on Prosthetics Research and


CHAPTER V

CONCLUSION

Summary

The purpose of this dissertation was to investigate three key factors related to drop-off detection with the long cane: cane-technique-related factors, user characteristics, and ergonomic factors. In this section of the dissertation, study findings, limitations, practical implications, and recommendations for future research are discussed.

The first paper (chapter II) investigated the type of cane technique used in drop-off detection, preferred cane technique, and years of cane use as cane-technique-related factors. Cane users performed significantly better when using the constant contact technique than when using the two-point touch technique. Preferred cane technique did not have a significant effect, while years of cane use had a significant effect on drop-off detection as it interacted with the type of cane technique used in drop-off detection. That is, experienced cane users' advantage over the less experienced cane users was larger when the two-point touch technique was used than when the constant contact technique was used.

In the second paper (chapter III), age and age at onset of visual impairment were examined as two of the key user characteristics in conjunction with the type of cane technique used in drop-off detection. There was no statistically significant interaction between any of the user characteristics and the type of cane technique used in drop-off
detection. Younger cane users detected drop-offs significantly better than older cane users, and cane users with earlier-onset visual impairment did significantly better than those with later-onset visual impairment in drop-off detection.

The final paper (chapter IV) investigated the effect of different types of cane tips on drop-off detection. Because many cane tips, including the marshmallow roller tip, had been designed with a specific cane technique in mind (e.g., marshmallow roller tip was designed to be used primarily with the constant contact technique), the effect of cane tip was examined in conjunction with the type of cane technique used in drop-off detection. Type of cane tip did not have a significant effect on drop-off detection when the constant contact technique was used for both tips. However, the constant contact technique combined with the marshmallow roller tip was better than the two-point touch technique combined with the marshmallow tip in detecting drop-offs.

Discussions on Overall Findings

The most significant and prevailing finding of this dissertation was the presence of constant contact technique’s advantage over the two-point touch technique in drop-off detection. Such advantage was present both as a main effect and simple effects. Particularly noteworthy was the large effect size of such advantage and its consequent practical significance. For example, the 50% drop-off detection threshold of the two-point touch technique was almost twice as large as that of the constant contact technique. Even for large drop-offs (5 and 7 inches), which could pose a serious risk of falling if missed, participants still missed 1 in 12 drop-offs when using the two-point touch technique, while they missed less than 1 in 40 when using the constant contact technique.
It is also important to note that such a large effect size of the constant contact technique’s advantage over the two-point touch technique was maintained even when the constant contact technique was used with the marshmallow roller tip, while the two-point touch technique was used with the marshmallow tip. Given this finding, coupled with the marshmallow roller tip’s ability to reduce the frequency of sticking against the walking surface (Lillie, 1987), the constant contact technique’s advantage may be maintained on rougher walking surfaces as well if it is used with a marshmallow roller tip.

As discussed in Kim, Wall Emerson, and Curtis (in press), one possible explanation for the constant contact technique’s advantage over the two-point touch technique may be proposed by combining the following two hypotheses: (1) two-point touch technique relies primarily on proprioceptive/kinesthetic perception (e.g., wrist angle or position of cane-holding arm), while the constant contact technique depends more on vibro-tactile sensitivities (e.g., changes in intensity of pressure on cane-holding-hand when the cane tip lands on the sunken surface) for detecting drop-offs, and (2) it is more effective to use vibro-tactile feedback than to use proprioceptive/kinesthetic feedback for detecting drop-offs. Chan and Turvey (1991) stated that the skin and muscle deformation of the cane-holding hand that corresponds to the hand-held probe’s moment of inertia was the key factor in depth estimation, suggesting vibro-tactile perception’s essential role in depth estimation with a hand-held probe. No other published studies directly related to this topic could be located.

Another possible explanation may be found in the fact that drop-off detection with the constant contact technique requires discrimination of two stimuli that are presented consecutively with no (or marginal in length) interval, while the drop-off detection with
the two-point touch technique involves comparison of two stimuli that are separated temporally and intervened by spatial displacement. In other words, when using the constant contact technique, sweeping the cane side to side with the cane tip on the walking surface at all times, the vibration the cane user feels through his cane-holding hand varies little during his approach to the drop-off. Immediately following such consistent pressure on his cane-holding hand, the cane user feels a distinctly higher intensity of pressure on his hand when the cane tip lands on the depressed surface past the drop-off edge. In contrast, when using the two-point touch technique, the cane user needs to determine whether the pressure on his cane-holding hand at the moment his cane tip lands on the sunken surface is different from a series of pressures he intermittently felt on his hand at the moments he tapped the walking surface with the cane during his approach to the drop-off.

Similar apparent advantage appears to exist for the constant contact technique in respect to proprioceptive/kinesthetic feedback as well. When using the constant contact technique, the cane user needs to discriminate the proprioceptive/kinesthetic stimulus (e.g., sagittal angle of the cane-holding wrist) he receives at the moment the cane tip lands on the sunken surface from the proprioceptive/kinesthetic stimulus that immediately preceded it with no intervening displacement of the wrist angle. When using the two-point touch technique, the cane user needs to determine whether, for example, the sagittal angle of his cane-holding wrist at the moment the cane tip lands on the depressed surface is different from the wrist angle formed at the moments of his cane taps on the walking surface during his approach to the drop-off; in this case, there is a temporal separation between the baseline and target stimuli. In addition, when using the two-point touch
technique, the cane user also needs to filter out potentially distracting proprioceptive/
kinesthetic input generated during the intervals (periods during which the cane tip is lifted
and moved from side to side) to compare the baseline and target stimuli. The 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 proprioceptive/kinesthetic and vibrotactile senses
(Gescheider, Bolanowski, Verrillo, Arpajian, & Ryan, 1990; Kaplan, Nixon, Reitz,

For practical purposes, it is most meaningful to view the effect of cane technique
practice (years of cane use), age, and age at onset of visual impairment in the context of
which cane technique should be selected for an individual in a given situation; this is
because the type of cane technique is the only variable among the important factors
related to drop-off detection that can be readily altered by the cane user. Cane technique
practice had a larger effect on drop-off detection performance when the two-point touch
technique was used than when the constant contact technique was used. One of the
possible explanations for such interaction may be proposed using the following two
hypotheses: (1) two-point touch technique relies primarily on proprioceptive/kinesthetic
perception while the constant contact technique depends more on vibro-tactile perception
for detecting drop-offs, and (2) it takes longer to develop proprioceptive/kinesthetic
perceptual skills needed to reliably detect drop-offs than to develop similar vibro-tactile
perceptual abilities required to consistently detect drop-offs. Although the literature
supports the notion that improvement of vibro-tactile sensitivities does not require
extensive practice (Diespecker, 1970; Fucci, McCaffrey, Curtis, & Blackmon, 1974;
Godde, Spengler, & Dinse, 1996; Maeda & Griffin, 1995; Schenkman, 1986), there does not seem to be a consensus in respect to the extent of practice needed to improve proprioceptive/kinesthetic sensitivities (Crilly, Willems, Trenholm, Hayes, & Delaquerriere-Richardson, 1989; Graydon & Townsend, 1984; Islam et al., 2004; Sims & Morton, 1998; Wolf, Barnhart, Ellison, & Coogler, 1997).

As mentioned above, the most useful interpretation of younger cane users’ advantage over the older cane users in drop-off detection can be made when it is viewed in the context of how it may affect the cane technique selection by a cane user. In other words, given the reduced ability to detect drop-offs reliably, coupled with the higher propensity to fall and often serious consequences of such falls among older adults, taking advantage of the constant contact technique’s ability to detect drop-offs more reliably appears more critical for older cane users than for younger cane users.

Younger cane users’ advantage over the older cane users in drop-off detection is consistent with previous literature on deterioration of perceptual sensitivities across different sensory modalities (Fozard & Gordon-Salant, 2001; Rubert, Eisdorfer, & Lowenstein, 1996). To be specific, literature supports the presence of age-related deterioration of proprioceptive/kinesthetic and vibrotactile sensitivities (Gescheider, Edwards, Lackner, Bolanowski, & Verrillo, 1996; Pai, Rymer, Chang, & Sharma, 1997), which appear to be involved in drop-off detection with the long cane. The reduction in the number of proprioceptors—expressly, muscle spindles that encode limb position and the rate of change in limb position—appears to underlie the age-related decline in proprioceptive sense (Liu, Eriksson, Thornell, & Pedrosa-Domellof, 2005). Similarly, decrease in density of Pacinian corpuscles with aging seems to be the underlying
biological change related to the decline in vibro-tactile sensitivities of older adults (Gescheider et al., 1996).

The advantage of cane users with earlier-onset visual impairment over those with later-onset visual impairment in drop-off detection may also need to be interpreted in the context of how it affects cane users’ cane technique selection decision. Given the significantly less reliable drop-off detection performance of the cane users who have later-onset visual impairment, the advantage of the constant contact technique may be more important for those with later-onset visual impairment than for those with earlier-onset visual impairment.

One of the hypotheses that can be proposed to explain this result is that there exist sensitive periods for maximal development of both proprioceptive/kinesthetic and vibro-tactile perceptual abilities. Given the presence of early-in-life sensitive periods in more thoroughly examined senses (e.g., vision, hearing), it is not unreasonable to suspect the existence of similar sensitive periods for proprioceptive/kinesthetic and vibro-tactile senses. However, the literature on this topic is too sparse to support this hypothesis (Drever, 1955; Facchini & Aglioti, 2003).

Study Limitations

Although the use of a repeated measures design allowed each participant to serve as his or her own control for the within-group factors (type of cane technique used in drop-off detection, type of cane tip used in drop-off detection), effects of between-groups factors might have been confounded by the variables that have not been controlled for. What appeared to have caused the largest confounding was the effect of the years of cane
use in the relationship between age at onset of visual impairment and drop-off detection performance. To be specific, the actual advantage of cane users with earlier-onset visual impairment over those with later-onset visual impairment might have turned out to be smaller in the absence of confounding by years of cane use. However, this confounding effect did not appear to be substantial given the fact that the effect of age at onset of visual impairment was still significant even after the earlier-onset and later-onset groups were equalized in respect to years of cane use by trimming the less experienced cane users from the later-onset group.

Another limitation of the study involves the smooth walking surface used in the study that might not have allowed potential effect of different cane tips on drop-off detection to appear. It is possible that rougher walking surface may make it more difficult for the cane user to discriminate drop-offs from walking surface irregularities, particularly when the constant contact technique is used since such irregularities may cause more sticking problem for the constant contact technique than for the two-point touch technique. However, the potentially negative effect of increased frequency of sticking on rougher walking surface may not be substantial when the constant contact technique is used with the marshmallow roller tip given the marshmallow roller tip’s ability to significantly lessen the propensity to stick on relative irregular walking surfaces (Lillie, 1987).

It is also possible that the difference in diameter between the two cane tips has confounded the result. However, such effect, if present, would have probably helped the marshmallow tip, since, at least conceptually, smaller diameter of the marshmallow cane
tip allows a sharper and quicker change of the cane tip’s movement trajectory—from horizontal plane to vertical plane—as the cane tip passes the edge of the drop-off.

Another possible confounding is related to the weight difference of the two cane tips. The heavier weight of the marshmallow roller tip compared to the marshmallow tip could have either helped or disadvantaged the marshmallow roller tip’s ability to detect drop-offs. However, accuracy of haptic depth perception with a hand-held probe with an attached weight (110 g) at the probe end did not appear to be different from that with a probe with no attached weight. (Chan & Turvey, 1991). This result does not support the hypothesis that a relatively small difference in weight of the cane tips could substantially affect drop-off detection performance. Furthermore, marshmallow roller tips tend to be larger and heavier than marshmallow tips due to its inherent need to integrate ball bearings into the cane tip. Given such, the difference in diameter and weight between the two cane tips is of limited importance for practical purposes (e.g., for a cane user who needs to select a cane tip from what is commercially available).

Last, the study included only two of the many widely used cane tips, which limits the generalizability of the study findings in respect to the effect of cane tips on drop-off detection. A small sample acquired through a nonprobability sampling method also limits the generalizability of the study’s overall findings.

Practical 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 due to the consumer’s
poor balance, O&M specialists may consider recommending the constant contact technique, particularly in anticipation of curbs or substantial surface elevation changes in the environment. Given the larger advantage in drop-off detection of the constant contact technique over the two-point touch technique for those who have less cane use experience, if only limited hours of cane training are available for a consumer, O&M specialists may consider training strategies that focus on developing adequate drop-off detection abilities with the constant contact technique rather than attempt to develop such abilities equally with both the two-point touch and constant contact techniques.

Last, given the almost identical drop-off detection performance of the marshmallow and marshmallow roller tips when the constant contact technique was used, it appears reasonable for the O&M specialists to recommend the constant contact technique with a marshmallow roller tip to reduce the frequency of sticking, if sticking poses a risk or annoyance to the cane user, without the fear of compromising the ability to detect drop-offs.

However, the findings of this study do not suggest exclusive instruction or use of the constant contact technique. Drop-off detection is only one of the measures of cane travel performance; other important measures of cane travel include obstacle detection and travel efficiency. A cane user needs to maintain adequate coverage of his walking path using his cane to avoid collision with obstacles that may cause falls or other collision-induced injuries. In addition, it is important for a cane user to travel to desired destinations efficiently as well as safely, particularly when extensive travel is required. Given such, advantages and disadvantages of each technique in respect to different aspects of cane travel, as well as the differences in cane users’ physical abilities and
environmental characteristics, need to be evaluated carefully before an appropriate cane technique selection decision is made.

Recommendations for Future Studies

Environmental factors need to be investigated in future studies to help us acquire a more comprehensive understanding of what factors determine how reliably drop-offs can be detected with the long cane. Given the fact that only two of the many widely used cane tips were included in this study, investigation of other cane tips is needed to further our understanding of the effect of cane tips on drop-off detection. Examination of biomechanical factors may also be helpful since it would allow us to analyze how different biomechanical components of cane techniques may affect drop-off detection. In addition, with a larger sample, analysis techniques that allow us to examine the relationship between specific predictor variables and the outcome variable while controlling for the other predictor variables in the model can be used. Furthermore, given the fact that drop-off detection is only one of the many functions of a long cane, it is imperative to include other measures of cane travel, including obstacle detection and travel efficiency, to obtain a more comprehensive understanding of how different factors affect various aspects of cane travel.

References


Appendix A

Human Subjects Institutional Review Board
Letter of Approval
Date: February 19, 2009

To: Amy Curtis, Principal Investigator
Robert Wall Emerson, Co-Principal Investigator
Dae Kim, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 09-02-27

This letter will serve as confirmation that your research project entitled “Analysis of Factors Related to Drop-off Detection with Long Cane” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: February 19, 2010