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Kyle Swim
The University of Toledo

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The effect of a laser guided cane on stride length in patients with Parkinson’s disease

Kyle Swim

Research Advisor: David L Nelson, Ph.D., OTR

Department of Occupational Therapy

Occupational Therapy Doctorate Program

University of Toledo Health Science Campus

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Abstract

Parkinson’s disease (PD) is a progressive neurological disease leading to multiple impairments, including disorders of gait. Past research has shown that visual cues may be beneficial in increasing stride length. The current study tests the effects of a laser beam cane on stride length in patients with PD using a single-subject, randomized alternating-treatments research design with two additional replications. The three subjects were males, aged 67, 62, and 83. A GaitRite sensory mat was used to record stride length. Each subject walked this mat 16 times, with equal numbers of randomly assigned trials in each condition (laser on and laser off). The laser cane seemed to enhance stride length in a person with relatively serious impairment, but it had little functional effect on two subjects with relatively less impairment. Although the laser cane did not appear to enhance gait in the two younger, more able subjects, there was evidence that the laser cane was used to guide gait, in that cane placement tended to precede the stepping foot in the laser-on condition. Additional research is needed that focuses particularly on persons with relatively severe gait deficiencies associated with advanced PD.
The effect of a laser guided cane on stride length in patients with Parkinson’s disease (PD), typically with onset between 55 and 60 years old (Parkinson’s Disease Foundation, 2006). Every year approximately 40,000 Americans are diagnosed with Parkinson’s disease (PD), typically with onset between 55 and 60 years old (Parkinson’s Disease Foundation, 2006). The prevalence of PD in America is one percent of the population over sixty years old (Kaminsky, Dudgeon & Billingsley, 2007). There is a broad array of conditions that patients with PD tend to experience, which includes impairments in range of motion, strength, coordination in fine and gross motor skills, oral motor skills, mood, and, in advanced stages, certain mental processes (Forwell, Copperman & Hugos, 2007). With regard to motor symptoms, PD patients typically exhibit tremors, rigidity, bradykinesia (slow movement), and postural instability. These symptoms are progressive in nature; however, timing and severity do vary from person to person.

Hoehn and Yahr (Hoehn & Yahr, 1967) identified five stages of PD. In the first stage a patient experiences unilateral symptoms, with little of no functional implications. A resting tremor is the most common symptom in stage one. In stage two there is midline or bilateral symptom involvement; mild trunk mobility and postural reflex problems are also likely. Stage three is often characterized by postural instability and mild functional loss. Stage four is classified as increased postural and functional disability. Although patients are generally able to walk, occupations of daily living become more challenging, especially due to increased difficulty with hand manipulation and dexterity. The individual is confined to a bed or a wheelchair in the fifth stage.

The initial symptom that most patients with PD exhibit is resting tremor, which increases with the presence of stress. Bradykinesia is debilitating to the patient’s daily life; it influences walking, eye blinking, and facial expression. Postural instability is another primary characteristic of PD. Postural instability is associated with complications such as falls, akinesia
Laser cane and stride length

(inability to initiate movement), forward leaning of the head and trunk, and shuffling gait. Along with these symptoms, patients also experience muscle rigidity and sometimes cog-wheeling (abnormal toning) (Crepeau, Cohn & Boyt Schell, 2003).

A patient’s initial response to medication can be dramatic; however, over time the benefits of medication begin to diminish or become less consistent. Medications such as levodopa and carbidopa can reduce symptoms of PD by restoring the brain’s supply of dopamine. In addition to levodopa and carbidopa, dopamine agonists (i.e., Parlodel, Apokyn, and Mirapex) can also combat the symptoms of PD.

Many of the symptoms of PD stem from impairment of the basil ganglia. Together with the cerebellum, the basal ganglia is responsible for the coordination of movement. In most cases the ultimate cause of Parkinson’s disease is unknown; however, heredity and environmental factors may play a role in the occurrence of PD (Forwell, Copperman & Hugos, 2007). A mutation in chromosome 4 has been linked to 5-10% of all PD cases; however, there are still uncertainties about the contributions of this mutation to the actual disease. Exposure to well water, pesticides, and farms are some environmental factors that have been correlated with PD (Conley & Kirchner, 1999).

The basal ganglia may also play a role in vision and spatial coordination. Patients with PD have reported difficulties in regards to the perception of space in questionnaire surveys. Patients with PD report difficulty navigating their way around visible objects in a known environment. Spatial contrast sensitivity may decrease as a result of basil ganglia dysfunction (Amick, Cronin-Golomb & Gilmore, 2003). Studies of higher-level cognitive abilities in patients with PD have shown impaired performance on tasks dependent on visuospatial processing (Cronin-Golomb & Amick, 2001), visuospatial problem solving (Cronin-Golomb & Braun, 1997), and spatial working memory (Owen, Beksinska, James, Leigh, Summers, Marsden, et al.,
Laser cane and stride length

1993). Visual impairment in patients with PD can also affect their postural mechanisms (Paulus, Straube & Brandt, 1984). Individuals without PD may be able to compensate for inadequate proprioception with proper vision. Because patients with PD tend to have dysfunction in proprioception, vision is of particular importance (Azulay, Mesure, & Blin, 2006).

Even though several authors have cited visual impairment in PD, vision has been thought of as a potentially therapeutic compensation for gait abnormalities. There have been attempts to find relationships between visual stimulation and aspects of gait. One of the first analyses of gait in people with PD was conducted by Martin (1967), who reported the usefulness of vision in assisting locomotor activity. Martin’s studies indicated that only particular visual stimuli were useful in improving gait. Martin studied transverse lines, zigzag lines, lines parallel to movement, thin and thick lines, and tape stripes without color contrast. Transverse lines spaced 18 inches apart with contrast colors on the floor were perceived to be the optimal visual locomotive facilitators. Researchers such as Azulay, Mesure, Amblard, Blin, Sangla, and Pouget (1999) have speculated as to how visual stimulation facilitates of gait. One possibility is that the lines draw attention to the stepping process; another possibility is that the stripes on the floor elicit a step in locomotion, as if setting a goal of foot placement (Azulay, Mesure, Amblard, Blin, Sangla, & Pouget, 1999).

Lewis, Byblow, and Walt (2000) have shown that patients with PD can increase stride length if suitable visual cues are provided. Decreased stride length is the most common form of gait trouble in people with PD, accounting for 35% of all gait disorders (Azulay et al., 2006). In people with akinesia, a phenomenon known as kinesia paradox can occur. Individuals with PD who experience a kinesia paradox can walk with visual cues over obstacles with significantly greater stride length (Kaminsky et al., 2007).

Optic flow (the motion of objects as the observer moves in relation to them) may also be
used to initiate gait. Azulay et al. (2006) reported that locomotion has a greater dependence on dynamic visual input as opposed to static visual input. Prokop, Schuebert, and Berger (1997) found that optic flow can systematically alter walking velocity, which is correlated with changes in stride length, without related changes in stride frequency. In Schubert, Prokop, Brocke, and Berger (2004), patients with PD walked on a treadmill in front of a hemispherical screen. The screen gave the illusion that all objects around the subject were moving at a constant rate. The illusion of optic flow increased the subject’s walking velocity as the objects moved at a faster pace. The increase in walking velocity also was associated with increased stride length.

Lewis, Byblow, and Walt (2000) used projected visual cues to research their effects on stride length regulation. The study involved 14 patients with PD and 14 healthy control subjects (matched for gender, age, and height) in baseline conditions with two types of visual cues: tape step length markers and subject mounted light devices. The study used a randomized, repeated measures, counterbalanced experimental design to compare stride length in patients with PD versus a healthy control group. Subjects participated in three different conditions. In the first conditions, subjects were told to walk down a 10 meter runway at their normal speed, ten times (20 trials) without any assistive devices. In the second condition, subjects were asked to walk down the same runway, in the same manner, but modifications were made to this runway: strips of 5 X 50 cm tape were placed along the runway, perpendicular to the path of gait, with the distance between these pieces of tape corresponding to the normal stride length of each subject. For the third condition the pieces of tape were removed from the runway, and the instructions remained the same. During the third condition subjects wore the device which projected two laser lines in front of the subject onto the runway. These laser lines were approximately 50 cm wide and were spaced at the same distance interval as the tape makers. The results showed that stride length and gait velocity increased in both the tape condition and the device condition. The
study found that stride length can be regulated in people with PD by using fixed visual cues without increasing central processing capacity or perceived effort.

Most research regarding the effect of visual cues on gait limit the use of visual cues to fixed prompts such as tapping or lines drawn on to a flooring material. Since people with PD cannot routinely rely on their various environments to present such fixated visual prompts, a method of visual projection onto a pre-existing environment might well be beneficial in enhancing locomotion in people with PD. A laser cane resembles a standard walking cane, but during weight bearing the cane projects a horizontal beam of light perpendicular to the individual’s direction of gait.

The purpose of the present study is to determine if the laser cane can increase stride length compared to a control cane without the visual cue projection. The hypothesis of the study is that a significant increase in stride length will be observed when using the laser projection as opposed to the non-laser projection baseline.

Method

Subjects

The initial plan was to recruit four subjects, but only three were available within the investigator's timelines. These subjects were patients from the Center for Neurological Diseases at the University of Toledo. A student research assistant made initial contact with the subjects, and follow up contact was made by the student investigator. Inclusion criteria for each subject were as follows: (1) stage 2.5 or 3 on the Hoehn and Yahr rating scale; (2) frequent episodes of freezing; (3) a regimen of medication for PD; (4) single point cane used for ambulation at least part of the time; (5) ability to follow simple directions; (6) no visual impairment; (7) current medical stability; (8) age 60 or older; and (9) functional endurance adequate to walk at least 50 meters without rest. The three subjects were males, aged 67, 62, and 83. All three subjects
preferred to use the cane on the right side.

Instruments

The laser cane used in the study was manufactured by In-Step Mobility Products Corporation. According the manufacturer, the cane was designed to assist the gait of those with Parkinson’s disease in regards to freezing of gait and stride length. The beam can be activated by a small red button, which could be toggled off for the laser-off condition. When weight activated, the cane projects a horizontal beam approximately .6 meters in length in front of the subject perpendicular to gait direction. The laser cane can be adjusted in height from 31” to 40” in 1” increments to accommodate subjects of varying heights.

Stride length was measured by the GaitRite walkway (CIR Systems Inc. Clifton, NJ 07012). The GaitRite walkway was 4.7 meters in length by 1 meter in width. The GaitRite walkway uses pressure sensors which are embedded into the carpeted mat in a horizontal grid. As each participant ambulates over the mat, built-in sensors compress under pressure, enabling the collection of spatial and temporal data. The area of the mat which contained the sensors is about 4.6 meters by 0.6 meters. The data were sampled from the walkway at a frequency of 80 Hz, which allows a temporal resolution of 11ms. The GaitRite mat was connected to a PC by a serial interface cable. The data collected by the GaitRite mat were processed and stored by an IBM compatible computer using GaitRite GOLD software.

The GaitRite system was investigated by Bilney, Morris and Webster (2002) in terms of one aspect of construct validity. Eleven subjects with Parkinson’s disease were matched by age to healthy control subjects. The GaitRite system measured the subjects' gait according to: step extreme ratio, step length, step time, heel to heel base support, single support percentage, double support percentage, and stance percentage. The GaitRite system differentiated the groups according to their gait. Because stride length is a function of step length (two steps make a
Laser cane and stride length 9

stride), this study provides some evidence of construct validity for stride length in the current study.

Procedure

The subjects participated in a single-subject, randomized alternating-treatments research design with two additional replications. One to three weeks prior to the study, the subjects were given the laser cane with instructions and a demonstration on its use. At this time, the subjects signed an informed consent form approved by the Institutional Review Board. The subjects were asked to use the cane one hour (no more or less, with half an hour with the laser light on and half an hour with the light off) during the entire week before the study. These instructions were meant to ensure that each subject had the same amount of experience using the cane and would be familiar with the device during the study.

Participants were asked to wear comfortable walking shoes and active clothing attire to their appointments for gait analysis. Each subject was instructed to walk at normal walking speed across the GaitRite mat with the verbal cue of “start walking.” Stride length was recorded during the initial part of the trial when the subject was ambulating over the GaitRite walkway. The remaining part of the trial focused on another study related to the effect of the laser cane in reducing episodes of freezing. After walking over the Gaitrite walkway the subject was instructed to walk out of the room and through a doorway. Once the subject was through the first doorway, he was instructed to turn around 180 degrees, and walk through another doorway into the other side of the classroom. Once back inside the room the subjects engaged in simple occupations that typically result in episodes of freezing, before returning to the starting position. A chair was provided to give the opportunity for the subjects to rest before beginning the next trial. The student investigator's research advisor accompanied the subjects throughout the trial by remaining within an arm’s length of each subject to reduce the risk of injury due to falls.
Each subject walked the course 16 times, 8 with the laser cane on and 8 with the laser cane off. The sequence of the 16 trials was randomly ordered, according to randomized blocks of four trials. After each trial the subjects were given a rest period of one minute; a chair was provided if the subject chose to sit during this time. Different testing days were used for the three subjects.

During the data collection for subject one, two trials (an on and off condition) were lost due to either software or human error. Therefore subject one's data analysis is limited to 14 trials instead of the planned 16.

Plan for data analysis

Mean stride length for each trial within each condition was graphed. Stride length is defined by GaitRite as the distance between two successive points of initial contact of the same foot. In the current study, stride length commenced with the left foot. The stride lengths for each participant were compared between the two conditions. The visual analysis consisted of evaluating: magnitude of mean difference between conditions, overlap between conditions, and trends (up or down across the 16 trials).

Results

The results for stride length are depicted in Figure 1. Initial visual analysis suggests that the laser cane increased stride length in subject three, but results were inconclusive in subjects one and two. Each point on the graph represents a mean of the strides in each trial. Subject one’s average stride length mean across all laser-on trials was 107.0 cm ($SD = 4.9$). With the laser in the off condition, subject one’s mean stride length mean was 110.0 cm ($SD = 2.6$). Overlap between the two conditions was high as shown in Figure 1. Subject two had a mean stride length with the laser on of 83.3 cm ($SD = 7.8$), and 88.3 cm in the off condition ($SD = 8.4$). Similar to subject one, the results for subject two provide no evidence of laser efficacy. The degree of
overlap between conditions was fairly high. Subject three had a mean stride length with the laser on of 61.5 cm ($SD = 4.6$), and 53.7 cm in the laser-off condition ($SD = 7.1$). This shows that the laser-on condition increased stride length by 7.8 cm on average. Overlap between the laser-on condition and laser-off condition was minimal, as shown in Figure 1. A trend could be seen of the laser-on condition continuing to have an impact in later trials.

While stride length was the main variable of the study, another variable was of interest. Since the GaitRite system also recorded cane placement, it was decided to look at how the placement of the cane changed under the two conditions. It was found that the cane was placed in front of the stepping foot more often under the laser-on condition than the laser-off condition in all three subjects, as shown in Table 1. This demonstrates that the laser visual cue was actually being used by the subjects.

Step length in subject three was found to be an interesting variable because it demonstrated asymmetry in the subject’s gait, as shown in Figure 2. Each subject has two step lengths, a left and right. Subject three had a left step length mean of 38.4 cm ($SD = 2.6$) in the laser-on condition and a mean of 36.4 cm ($SD = 4.2$) in the laser-off condition. Subject three had much smaller steps on the right side, with step length mean of 21.4 cm ($SD = 2.8$) in the laser-on condition and a mean of only 16.2 cm, ($SD = 3.8$) in the laser-off condition. It was noted that subject three seemed to use the laser as a guide for his left foot while stepping; however, when the right foot was brought forward, it was brought short of where the lead foot was placed. Subjects one and two had relatively symmetrical step lengths.

When asked how frequently each subject uses a single point cane, Subjects 1 and 2 stated that they use a cane occasionally. However, Subject 3 stated he uses a cane frequently both inside and outside his home.
Discussion

The purpose of this study was to investigate whether there would be a difference between the laser cane and a control condition in terms of stride length in patients with PD. The laser cane led to a noticeable improvement in stride length for subject three. In contrast, the results for subjects one and two were not supportive of the proposition that the laser cane would increase stride length. However these two subjects had relatively little impairment who used a cane only occasionally in daily life for general ambulation.

One could conclude that the laser cane was found to be unnecessary by subjects one and two, and therefore no significant impact on stride length of these individuals was recorded. Subject 3 on the other hand had relatively more impairment, and he may have viewed the laser as an important visual cue for footfall. One indication of subject three's relative impairment is that his stride length is much less than the other two subjects, whether the laser light was on or off. Another indication was subject three's asymmetry of gait. From observation it appeared that Subject 3 moved his left foot toward the laser projected on the floor, while his right foot dragged behind. A third indication is that subject three experienced several episodes of freezing while walking the course designed by the other student investigator.

Table 1 shows that cane placement occurred in front of the stepping foot much more often in the laser-on condition than the laser-off condition, leading one to believe that cane placement may have had some impact on all three subjects. With the exception of subject three, subjects one and two seemed to show trends of both conditions converging. Possibly with each passing trial, the patients gained familiarity with the device, making the laser-on condition less and less distracting.

Lewis, Byblow, and Walt (2000) found visual cues were able to increase stride length in patients with PD. They compared 14 PD patients to 14 healthy control subjects and found that
both tape step length markers and light devices mounted on subjects were successful in increasing stride length compared to an environment without such visual cues in PD patients. In another study, Schubert, Prokop, Brocke, and Berger (2004) found that visual cues in the form of optic flow were able to increase stride length in PD patient. Similar to our study, authors of these two past research projects have suggested that participants with relatively high levels of impairment are the ones who benefit the most. Additional research is needed to find out which specific visual cues work best, and at what level of functional impairment are these visual cues needed. Much of prior research regarding the effect of visual cues on gait limit the use of visual cues to fixed prompts such as tapping or lines drawn on to a flooring material. The key is to find an aesthetically pleasing, mobile device, which can provide needed visual cues for foot placement. The laser cane has potential to increase stride length to reduce episodes of freezing of gait in certain populations.

A limitation of this study is that medication timing was not controlled for. Perhaps subjects one and two might have benefited from the laser cane when particularly fatigued or when off medication. Other limitations include a small sample size, testing restricted to a particular day that might not be representative of other days and situations, and a limited number of trials. It is important to point out that with this population it is possible to have too many trials. Fatigue seemed to be evident in subjects 2 and 3 toward the end of the trials; an important balance must be struck between obtaining enough trials and running into fatigue. While it was difficult to recruit subjects that fit the inclusion criteria, it would be interesting to conduct this same study on additional patients with relatively lower levels of function. It appears that for those who need visual cues the laser can provide assistance in increasing stride length. A limitation of the laser cane is that it cannot be used very well in daytime outdoor settings due to the vast amounts of sunlight.
Future research should include larger samples and study the efficacy of the laser light with regards to medication timing. It would also be useful to observe patients with PD using the laser cane in naturalistic settings to get a true understanding of how the cane functions with daily occupations. The current study has important implications for patients with PD as well as for therapists treating them. For lower functioning patients with PD, a laser cane has the potential to enhance gait and thereby influence quality of life.
References


Table 1.

Cane placements preceding the stepping foot across the two conditions (ratio of forward cane placements to all cane placements that were measurable). All three subjects appeared more likely to place the cane in front of the stepping foot in the laser-on condition than in the laser-off condition.

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<td>46.3</td>
<td>15/49</td>
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Figure 1. Stride length comparing laser-on and laser-off conditions.
Figure 2. Step length for subject three, demonstrating difference between right and left foot.

Subject 3 Left Step Length

Subject 3 Right Step Length