Effects of a laser cane on functional gait in patients with Parkinson's Disease

Morgan Wilcox
The University of Toledo

Follow this and additional works at: http://utdr.utoledo.edu/graduate-projects
Effects of a laser cane on functional gait in patients with Parkinson’s disease

Morgan Wilcox

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

Department of Occupational Therapy

Occupational Therapy Doctorate Program

The University of Toledo Health Science Campus

May 2010
Abstract

Parkinson’s disease (PD) is a degenerative neurological disorder with multiple impairments, including freezing of gait (FOG). Prior research indicates that visual cues may be beneficial in improving gait and reducing FOG in patients with PD. The current study tests the effects of a laser beam cane on FOG 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 walking course simulating environments in which patients are prone to FOG was created to study the efficacy of the laser cane on functional gait. Each subject walked this course 16 times, with equal numbers of randomly assigned trials in each condition (laser-on and laser-off). The number of freezes per trial and trial duration were recorded. Subjects 1 and 2 had only one incidence of FOG between them, so results on this variable were moot. Subject 3 had notably less freezing episodes in the laser-on condition. Trial duration scores showed no difference between conditions for Subjects 1 and 3, but the laser-on condition appears to have slowed down Subject 2. These results suggest that a patient with relatively advanced PD and frequent episodes of FOG might benefit from the laser cane, whereas this study provided no evidence of efficacy for subjects with relatively few impairments.
Effects of a laser cane on functional gait in patients with Parkinson’s disease

Approximately 1% of the population is affected by a neurological disorder known as Parkinson’s disease (PD) (Forwell, Copperman, & Hugos, 2008). PD is a degenerative disorder that affects the substantia nigra and causes a decrease in the production of dopamine (Pulaski, 2003). This degeneration is progressive and is rarely seen in adults younger than 40 years of age, with an average age of onset of around 60 years (Dirette, 2007).

The degenerative nature of PD results in a gradual onset of symptoms that can be seen through five stages defined by Hoehn and Yahr (Forwell et al., 2008). In these stages, the patient’s symptoms range from little or no functional limitations in the first stage to wheelchair confinement in the final stage. The effects of PD have implications in every area of occupation (Pulaski, 2003). Motor impairments are the cardinal signs of the disorder: tremor, rigidity, bradykinesia, and postural instability (Forwell et al.). Non-motor aspects of PD such as cognitive impairments and depression can also effect a person’s daily occupations (Dirette, 2007).

Freezing of gait (FOG), the inability to take a step, is a troubling symptom of PD. FOG tends to occur when turning, at the start of movement, when walking through a narrow space, or just before reaching a destination (Okuma, 2006). The pathophysiology of FOG is not completely understood. Okuma listed possible contributions to this phenomenon, including co-contraction of opposing muscle groups in the legs, a decrease in attention to walk, and postural instability. Okuma also mentioned associations between FOG and a relatively long duration of PD and a relatively long dopaminergic treatment. Giladi et al. (2001) reported data supporting the idea of an association between the severity of the disease and the occurrence of freezing. In their study, 69% of the patients in the most severe stages on the Hoehn & Yahr scale (stages 4 and 5) experienced FOG. Their findings also support earlier reports that a longer duration of
levodopa medication treatment is associated with FOG. Davidsdottir, Cronin-Golomb, and Lee (2005) reported that 44% of their survey participants with PD experienced freezing of gait. This occurrence was found to be associated with a longer duration of PD and also with higher scores on the Hoehn & Yahr scale.

Giladi et al. (2001) have stated that FOG is considered to be the most disabling symptom of PD because it can compel the patient to remain at home or to use a wheelchair. This disablement is due to the risk of falling associated with FOG and the variety of situations in which it occurs. In addition to the four types of FOG stated previously (turning hesitation, start hesitation, tight quarters hesitation, and destination hesitation), Okuma (2006) also noted that stressful situations may contribute to the onset of FOG (e.g., when a patient with PD has a time constraint for a task, such as crossing a street before the traffic signal changes).

Moore, Peretz, and Giladi (2007) used a quality of life (QoL) questionnaire, the PDQ-39, to assess the effects of PD on 118 patients. It was found that the severity of FOG directly affects QoL, as do the duration and severity of the disease. Overall, Moore et al. emphasized the episodic nature of PD by stating that patients have no way to prepare for freezing and that public episodes of FOG can be embarrassing. This embarrassment often results in patients avoiding social situations and in turn reduces their QoL.

The success of managing FOG may depend on the medication level at the time of the freezing episode. Increasing the level of medication may be beneficial in reducing freezing (Okuma, 2006). A more invasive medical intervention for FOG is deep brain stimulation of the subthalamic nuclei or the globus pallidus (Okuma, 2006).

Nieuwboer, Feys, Weerdt, and Dom (1997) suggested using cognitive strategies such as counting while walking in order to establish rhythm of gait as another method for managing FOG. However, while cognitive strategies may be effective for some patients, more research has
been devoted to understanding external cues. Okuma (2006) recommends using external cues as another option for controlling FOG. Nieuwboer et al. (1997) defined cues as “contextual or spatial stimuli which are associated with the behaviour to be executed, through past experience” (p. 127). As a way of preventing freezing, Nieuwboer et al. mentioned two types of external cues: visual or auditory.

Theorizing about a possible physiological mechanism responsible for the efficacy of external cues, Nieuwboer et al. (1997) described how motor plans are generated in the pre-motor areas of the cortex, including the supplementary motor area (SMA) for intrinsically guided movement and the ventral pre-motor area (vPMA) for visually-guided movement. Through the circuitry of the basal ganglia and the thalamus, the motor plan is reinforced. Both of these areas then project to the primary motor cortex, which generates the movement command. In persons with PD, the SMA pathway is affected so perhaps the vPMA upregulates as a possible compensatory mechanism. Since this area is the visually guided pathway, external cues may contribute to improved motor functions in patients with PD.

Visual and auditory cues have been studied separately and in combination to determine their effectiveness. Auditory cues frequently involve metronomes, but music with a rhythmic beat can also be used (Rubinstein, Giladi, & Hausdorff, 2002). Cubo, Leurgans, and Goetz (2004) used metronome pacing to examine gait freezing in patients with PD. The experimenters randomized the order of the control and metronome conditions, and a videotape of each trial was evaluated by the first author who was blinded to the conditions. They argued that some improvement occurred by using the metronome; however, the change was not statistically significant.

Davidsdottir, Cronin-Golomb, and Lee (2005) reported that 81% of their participants with PD who experience freezing use strategies to re-establish movement. These strategies
include visual methods, such as focusing on a target. Other visual cues include markers placed on the floor and an inverted walking stick that provides a target for patients to step over.

Suteerawattananon, Morris, Etnyre, Jankovic, and Protas (2004) studied both auditory and visual cues on aspects of PD patients’ gait other than freezing. They used a Latin square design and observed twenty-four patients with PD while walking with visual cues, auditory cues, and both cues combined. They reported that visual cues significantly increased stride length and that auditory cues resulted in significant improvements for both gait speed and cadence. The combination of these cues did not increase the effects any more than using just the one type alone. This may be because the patients divided their attention between the cues when used in combination. A study done by Kaminsky, Dudgeon, Billingsley, Mitchell, and Weghorst (2007) took baseline measurements of freezing for six subjects before introducing visual cues in the form of “virtual cueing spectacles” (p. 439). These specialized goggles provided the subjects with visual cues in the form of horizontal lines of light that scrolled forward as the subjects raised their heads and walked. The measurements taken during the intervention phase show a clear reduction in freezing episodes for one subject; however, results for the other five subjects are not clear. Increases in freezing during the intervention phase may have been influenced by illness or changes in medication which were reported in the results. All six subjects reported an improvement in mobility while using the virtual cueing glasses.

Azulay, Mesure, Amblard, Blin, Sangla, and Pouget (1999) compared static to dynamic visual cues by including in their study a stroboscopic lighting condition (i.e., flashing lights). Both lighting conditions were equivalent in brightness. Transverse white lines on the floor were used as cues for the patients during the normal and stroboscopic lighting conditions. The markers improved stride length and velocity during the normal light condition. When the stroboscopic light was used, the velocity and stride length were significantly reduced. These
results support Azulay’s theory that a momentary cue is not enough to reduce improve gait in patients with PD; rather the subjects need to continuously see the cues. Azulay, Mesure, and Blin (2006) theorize that stroboscopic lighting acted to “suppress selectively and completely dynamic visual cues (optic flow)” (p. 193). The patients perceive the lines moving while they are walking during normal lighting conditions. The addition of the stroboscopic light removes this perceived motion and thereby cancels out the visual cue needed by the patients with PD.

Most of the previous studies on visual cues have utilized floor markers. This is not a feasible method for patients to use while performing their daily occupations, except in certain areas of the home. In contrast a device such as a laser-emitting cane has the potential to help patients when they travel outside of their homes. Only one study has investigated the use of a laser attached to a walking device. Kompoliti, Goetz, Leurgans, Morrissey, and Siegel (2000) studied the efficacy of visual cues on 28 patients with PD who were “on” their medication. The variables measured in the study were the total time it took the patients to walk the 60-ft course, the number of freezing episodes, and the ratio of walking time to the number of freezes. The subjects were randomly assigned to the order of the three conditions (laser beam stick, modified inverted walking stick, and control) and were instructed before beginning the trials on how to use the two canes in order to familiarize the subjects with the devices. The results of the study show that neither cueing stick produced statistically significant improvements in gait speed or FOG, although a possible floor effect may have prevented observable improvements.

Research on using the laser beam cane as a visual cueing device is in its early stages, and the evidence has not been conclusive. The current study has the purpose of expanding knowledge of the efficacy of using a laser beam cane for people with PD. The first hypothesis of the study is that there will be a difference between the laser cane and a control condition in terms of freezing of gait in patients with PD. This study will also test the efficacy of the laser cane in
terms of duration required to walk a designed course involving doorways, tables, and a simple occupation of retrieving a water container from a refrigerator and pouring a glass of water. This walking course was set up to simulate environments in which patients with PD are prone to freezing of gait.

Method

Subjects

The original 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 contacted the subjects by phone to inform them about the study. One of the student researchers followed up with each subject to confirm his interest in the study and schedule dates for receiving the cane and for participating in the study. 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.

Instruments

The subjects used a laser beam cane provided by In-Step Mobility Products Corporation. The cane had a weight activated laser beam on the tip which projects a horizontal beam in front of the subjects. The beam can be activated by a small red button, which could toggle off the beam for the comparison (laser-off) condition. The cane can be adjusted in one inch increments from 31 to 40 inches so that the height was individualized for each subject.

Another study was being conducted simultaneously by a student researcher who utilized the GaitRite motion analysis system to collect data during the trials. The GaitRite is a 14-foot
mat with embedded pressure sensors. It was used to detect the footfalls of the subjects during the first part of each trial of the current study (see Procedure below). The mat determined and recorded the stride length and other gait variables.

Procedure

This study used a single-subject, randomized alternating-treatments research design with two 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.

A walking course was set up for the study which simulated environments in which patients with PD are prone to FOG. The previous study done by Kompoliti et al. (2000) that utilized the laser cane incorporated very few environmental stimuli to induce FOG, and this might have contributed to the ambiguous results and possible floor effects. The study done by Cubo et al. (2004) used an obstacle course when measuring FOG to “maximize the likelihood of freezing” (p. 508). This course included walking through doorways and turning. Another study done on the topic of gait in people with PD had the subjects walk between chairs set 1 meter apart, turn 180 degrees, and walk back through the chairs (Protas et al., 2005).

At the start of the current course (see Figure 1), the subject walked across the GaitRite mat and through a doorway into a hall. He then turned 180 degrees and walked back through another door next to the first. The subject then turned, walked to a refrigerator, and retrieved a pitcher that they carried about 15 feet to a counter. He then reached into a cupboard to get a cup
and poured water from the pitcher into the cup. The subject could then drink the water, or leave it on the counter before turning almost 180 degrees and walking across the room and through another doorway so that he finished where he started the course. Tables and chairs were set up in the room to make a narrow path and potentially elicit gait problems.

The faculty advisor walked behind and to the non-cane side of the subjects in order to be ready to prevent any falls. The subjects decided on which side they used the cane; however it is typical for patients to use a cane on his or her strong side if there is asymmetry and on the dominant side if there is no asymmetry. All three subjects used their right hands to hold the cane.

Each subject walked the course 16 times, 8 with the laser cane on and 8 with the laser cane off. The subjects had a rest of one minute between trials during which a chair was provided so they could sit if they chose to do so. The sequence of the 16 trials was randomly ordered, according to randomized blocks of four. Two student investigators independently recorded the number of freezes per trial using an event timer hidden underneath a towel and also independently recorded the duration per trial with pocketed stopwatches.

The plan for data analysis was to compute the correlation for Lag 1 scores on each variable, as described by Kazdin (1984). Lag 1 correlation is synonymous with the term autocorrelation, whereby according to Kazdin “the correlation is computed by pairing adjacent data points ... and computing a correlation coefficient” (p. 248). If the correlations are not statistically significant, it could be assumed that serial dependency is not present, so parametric analysis could be computed to test the hypothesis. However, if statistically significant Lag 1 correlations suggest serial dependency, the randomization tests as described by Kazdin could be used to test the hypotheses.
Results

Inter-rater Reliability

Overall, inter-rater agreement was very strong. For Subject 1 both observers agreed that he had no freezes so an intraclass correlation coefficient (ICC) could not be computed for freezes. The ICCs for freezes for Subjects 2 and 3 were 1.00 and .88 respectively. The ICCs for walking course duration for Subjects 1, 2 and 3 were .88, .98, and .99 respectively.

Freezing of Gait

The primary variable being measured in this study was the number of freezing episodes observed during each trial. It was found that Subjects 1 and 2 did not have a significant number of freezing episodes across all trials (0 and 1, respectively), so the efficacy of the laser cane could not be determined for these subjects. However, Subject 3 had 24 freezing episodes during the 16 trials (see Figure 2). Seven were with the laser cane on, while the other 17 were under the no-laser condition. The average number of freezes per trial for Subject 3 were 2.1 ($SD = 1.4$) for the off condition and 0.9 ($SD = 0.8$) for the on condition.

Visual analysis of Subject 3’s freezes as depicted in Figure 2 suggest that there were fewer freezes under the laser-on condition in early trials but that there might have been a downward trend in the number of freezes in the laser-off condition. A lag 1 score was calculated, and it was determined that there was no autocorrelation between trials ($r = -.14$). Tests for skewness resulted in small values (-.29 for the off condition, .28 for the on condition). Therefore it was decided to perform a two tailed t-test. These results showed a statistically significant difference between conditions for Subject 3 in favor of the laser-on condition, $t(14) = 2.22, p = .043$.

Trial Duration

The results of each subject in terms of trial duration are represented in Figure 3. The
graphs for Subjects 1 and 3 show no difference between the conditions in terms of trial duration as evidenced by overlap between the conditions. The average trial times for Subject 1 for the laser-on and off conditions were 58.6 seconds and 57.3 seconds respectively. Subject 3 also had minimal difference in average trial times for the conditions (128 seconds for the laser-on condition and 127.4 seconds for the off condition). Thus, analysis of the trial times for these subjects showed that the efficacy of the laser cane appears to be inconclusive.

For Subject 2 the average trial times in the laser-on and -off conditions were 76.3 seconds and 72.1 seconds, respectively. The graph for Subject 2 also illustrates a decrease in speed for both conditions as the study progressed, yet the laser-on condition consistently had higher trial times. No statistical analyses of trial duration were conducted because the laser cane clearly did not enhance walking speed for these three subjects.

Informal observations supplement the testing of the main hypotheses. Subject 2 demonstrated multiple freezing episodes while attempting to sit on a chair and again when moving from sitting to standing. This was not part of the predetermined course and thus could not be included in the formal results. Subject 3 stated that he felt as though his right foot was “dragging” when walking with the laser cane turned off. This subject also stated that too much force was required to activate the laser light. Subject 1 tended to talk during each trial, thus possibly increasing course time.

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 at home and in the community.

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 freezing of gait in patients with PD. A walking
course was designed for this study to create conditions which frequently elicit FOG. Subjects 1 and 2 demonstrated so few freezing episodes during both conditions that no conclusion concerning the laser cane can be made. The lack of FOG could possibly be a result of medication management or less severe gait impairments in these subjects.

On the other hand, there is a real possibility that the laser cane decreased freezing in Subject 3, who had high numbers of FOG (24 instances) throughout the study and demonstrated significantly less freezing episodes when the laser was on. However, the statistical analyses performed on the data for this subject were based on the assumption that each trial was independent of the others, and this is always a questionable assumption in the analysis of single subject experiments (Kazdin, 1984). The visual analysis of Figure 2 was not convincing by itself due to a possible downward trend suggesting that the subject might have been improving on his own in the laser-off condition; thus the results should be interpreted with caution. Taken in combination, the results of Subjects 1, 2, and 3 appear to suggest that the laser cane has best potential for patients with relative severity of gait problems.

Trial duration was measured because a shorter trial time would be reflective of decreased freezing and improved fluidity of gait. The results show little to no variation between the average trial times for each condition for Subjects 1 and 3, but Subject 2 seemed to have longer trial durations when the laser was on (i.e., the laser appears to have slowed down Subject 2). However, the assumption that speed reflects gait quality is questionable. Slow walking may be an unexpected positive outcome reflecting safety and consistency during functional mobility. It is possible that the increase in trial time could be due to an increased awareness of the cane when the laser light was on. Subject 3’s verbal report concerning the insensitivity of the tip of the cane in activating the laser may have increased his attention to the device and inadvertently slowed his walking pace. Also, the subjects were aware of the purpose of the study and thus may have been
inclined to attend to the laser light. The subjects also varied in their use of single point canes for mobility outside of the study, which may have impacted gait performance with the laser cane.

The study conducted simultaneously by the other student investigator detected footfall patterns using the GaitRite system. From these data it was determined that when the laser was on, cane placement tended to precede the foot whereas the cane was placed perpendicular to the foot when the laser was off. This suggests that the subjects used the laser as a target, which could further explain Subject 2’s decreased speed during the on condition.

Freezing episodes were significantly decreased for Subject 3 during the laser-on condition in the current study. This is similar to a study by Kaminsky et al. (2007) in which one participant was described as having a “clear and immediate” decrease in FOG when using visual cueing spectacles that projected scrolling lines as visual targets. The other five participants in this study showed high variability, and thus further conclusions could not be made. In the current study, Subjects 1 and 2 did not demonstrate a significant number of freezing episodes to observe differences between conditions. This floor effect was also seen in a study by Kompoliti et al. (2000), in which the average number of freezes per trial was only one for each condition.

In the current study, the laser cane decreased walking speed for Subject 2. In contrast, Sidaway, Anderson, Danielson, Martin, and Smith (2006) and Lewis et al. (2000) both found that floor markers (pieces of tape placed at intervals on the floor) significantly increased gait speed. Lewis et al. also found improvement in gait speed when a laser beam device worn by the patients projected two beams on the floor in front of the subject that were spaced the same as the floor markers used in the other condition. On the other hand, Kompoliti et al. (2000) found similar results to the current study in that the laser beam stick increased trial time when compared to an unassisted walking condition (42 seconds compared to 35 seconds). Cubo, Moore, Leurgans, and Goetz (2003) also found that trial time increased when subjects used a laser-on wheeled
walker than in the control condition (50.1 seconds and 45.9 seconds, respectively).

A study by Azulay et al. (1999) examined the influence of the dynamic perception of motion of floor markers induced by the subject’s walking on gait speed. They found a significant increase in speed when the subjects walked using stripes as targets on the floor. However, when a stroboscopic light was added to suppress the perception of movement of the floor markers when walking, a significant decrease in gait speed was observed. The laser beam cane in the current study projects a single line and therefore does not provide a dynamic visual cue, thus providing a possible explanation for the increase in trial duration that is consistent with prior research.

One factor that the current study did not focus on was the medication state of the subjects during the study. Both Kompoliti et al. (2000) and Cubo et al. (2003) scheduled their trials to be completed when the subjects were “on” their medications, and this may have influenced their results. The current study also differed from prior studies in that it examined functional mobility in a more naturalistic setting and incorporated an occupation-based task. Other limitations include a possible floor effect evidenced by a lack of FOG episodes experienced by the first two subjects, a small sample size, and course limitations which did not allow for inclusion of FOG episodes that occurred when the subjects were going into/out of the resting chair (as occurred for Subject 2).

FOG can lead to falls and thereby influence quality of life of patients with PD. A fear of falling may result in patients' limiting their socialization within the community. Devices that give patients confidence as well as improve gait performance should be introduced individually in order to determine possible effects on functional mobility. It can also be argued that the laser cane can increase gait safety and consistency by slowing down the subjects, as evidenced by the decreased speed of subject two when utilizing the laser cane.
Future research is necessary on the efficacy of the laser cane for patients with PD. This research could focus on improving the device to determine if projecting the laser further out in front of the patient would have an impact on FOG while also encouraging better posture while walking. The laser light could also be incorporated into a quad cane for increased stability during functional mobility. Increasing the sensitivity of the cane so that the laser can be activated with a lighter touch would also be another area for future studies to address. Adding a second laser beam to add in the element of dynamic perception of motion may also be an area for future research in this field of study. Future research should include larger samples and study the efficacy of the laser light when "on" versus "off" medication. It would also be useful to observe the patients in natural settings which potentially induce FOG (e.g. elevators, crossing streets) rather than recreating these situations in a lab. Future research should focus on regular cane users with relatively severe gait impairments including FOG to advance understanding of the efficacy of visual cures and the laser cane in terms of functional mobility.

Acknowledgment

I wish to acknowledge the kind assistance of Michelle Masterson, PT, Ph.D., for helping orient me to the GaitRite equipment and for providing generous access to this equipment.
References


Figure 1.
Diagram describing the walking course. The subject walked across the GaitRite mat, exited and re-entered the room via doors, retrieved a pitcher of water from the refrigerator, poured a glass of water at the sink with an option to drink, and walked back to the starting point though an arrangement of tables.
Figure 2.

Number of FOG episodes experienced by Subject 3 during the study across randomly ordered trials with laser-on versus laser-off conditions.
Figure 3.

Duration in seconds required by Subjects 1, 2, and 3 to walk the course across randomly ordered trials with laser-on versus laser-off conditions.