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# The Effects of Manipulating Spatial Location of Visual Cue Placement on Gait Among Individuals with Parkinson's Disease: A Pilot Study

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**ABSTRACT.** *Aims:* To investigate the effect of manipulating the spatial location of a visual cue used to manage gait impairment among individuals with Parkinson's disease. *Methods:* Six individuals with Parkinson's disease who experience severe freezing of gait were asked to complete the Timed Up and Go test three times in each of the following conditions: no cue, cue presented at the users feet, cue presented at a distance equivalent to step length, and cue presented at a distance equivalent to stride length. Step length, velocity, walker positioning, and time taken to complete a 180 degree turn and the Timed Up and Go test were recorded. *Results:* Visual cueing led to an improvement in 4/5 outcome measures with magnitude of improvement being dependent upon the spatial location of cue presentation. *Conclusions:* Findings suggest that visual cueing and the spatial location of cue presentation are highly individualized in terms of managing gait disturbance.

**KEYWORDS.** Parkinson's disease, freezing of gait, visual cueing, Mobilaser, gait dysfunction

Parkinson's disease (PD) currently affects over 100,000 Canadians, and with approximately 5,500 new cases in Canada being diagnosed each year, that number will continue to increase as the population ages (Bloem et al., 2004). Postural instability and gait impairment have been reported to impact negatively on an individual's independence and ability to actively engage in meaningful occupations

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(Giladi et al., 1997; Lindholm et al., 2014). Specifically, these impairments lead to an increased risk of falls and/or increased anxiety associated with fear of falling (Lindholm et al., 2014). One safety challenge faced by many patients with PD is freezing of gait (FoG). Defined as ‘a brief, episodic absence or marked reduction of forward progression of the feet despite the intention to walk’ (Nutt et al., 2011), FoG may lead to falls, and a loss of independence, thus making it one of the most debilitating motor symptoms of PD (Bloem et al., 2004). Studies suggest that approximately 60% of individuals with PD experience FoG within 10 years of being diagnosed (Bloem et al., 2004; Giladi et al., 2001; Lamberti et al., 1997), and that up to 70% of individuals with PD report experiencing at least one fall per year (Balash et al., 2005). These problems not only limit mobility and independence, reduce safety, and significantly affect quality of life (Moore et al., 2007), but place significant demands on the healthcare system. For example, among individuals with PD, over 75% of injuries sustained from a fall require healthcare services (Gray et al., 2000; Wielinski et al., 2005). The increased risk of falls associated with PD is particularly important, not only because of the propensity for injury, but also because of the fear and anxiety related to decreased functional mobility that ultimately contributes to a loss of independence, increased risk of isolation and depression, and an overall reduced quality of life (QoL; Benatru et al., 2008; Bloem et al., 2004; Lindholm et al., 2014; Moore et al., 2007).

While pharmacological management and surgical procedures have proven to be effective strategies in mitigating some symptoms of PD, they have minimal effects on reducing fall risk (Bloem, 1992; Grimbergen et al., 2004). In fact, in some cases they have been found to exacerbate gait disturbance (Bloem et al., 2004; Lamberti et al., 1997), thus leading gait impairments to become one of the most incapacitating symptoms (Blin et al., 1990). Therefore an investigation into rehabilitation strategies that are focused on managing these symptoms is an important and much needed undertaking.

External cueing is one strategy that has emerged as a promising nonpharmacological option to help normalize gait patterns and manage FoG (Bloem et al., 2004). External cues can be presented in the form of tactile, auditory, and visual information that can trigger movements or provide rhythmic or spatial support to improve the quality of movements (Rochester et al., 2005). Cueing is believed to work by evoking increased sensory stimulation that directly focuses attention on the gait task, thereby shifting the locus of control from the automatic control of the impaired basal ganglia to other nonimpaired conscious pathways (Glickstein et al., 1991). While improvements to gait have been realized with both tactile (Jenkins et al., 2009; Novak and Novak, 2006) and auditory cues (Nombela et al., 2013; Spildooren et al., 2012), Rahman et al., (2008) suggests that visual cueing might be the most effective strategy. In this study, 31.5% of participants reported that visual cues improved their mobility, as compared with 27.7% and 19.2% reporting tactile and auditory cues (respectively) to be effective.

Initial evidence in support of visual cueing as an effective rehabilitation strategy was provided by Morris et al. (1996), who examined the effects of using visual floor markers on the walking pattern of 54 individuals with PD. Results suggested that the ability to generate a normal stepping pattern is not lost in PD, as evidenced by the ability of participants to elicit normal stride length when using the visual cues.

Similar findings were also reported by Jiang et al., (2006) who observed that visual cues were effective at improving gait among 14 individuals with PD. The visual cues used were high contrast transverse lines on the floor and were found to result in increases to both pace and stride length.

Although significant improvements are realized when using visual cues such as transverse lines on the floor, there are obvious practical limitations with adopting this as a widespread approach. For example, while it may be possible to adapt the home environment to support a visual cueing approach (i.e., placing transverse lines on the floor), this would not be feasible to accomplish for settings outside of the home (e.g. doctors office, grocery store). As a means to overcome this limitation, two products have been commercialized. The first product called the U-Step walker (In Step Mobility, 2009), is a wheeled walker that contains a built in cueing device that emits a laser beam of light on the ground. The second product, called the Mobilaser (MAP/CIR Inc., 2011), is a stand-alone portable cueing device that can be attached to either a cane or a walker. A laser is emitted from an articulating head that can be adjusted to properly align the visual cue while the device is mounted in various positions specific to the design of each mobility aid. For both of these products, a transverse line of light is directed onto the ground immediately in front of the user. As the user walks, the laser line progresses with the mobility aid and acts as a dynamic stimulus that users are asked to focus on and step over with each step taken.

To date, several studies have evaluated the effects of using dynamic visual laser cues to improve gait among individuals with PD in both laboratory and home settings. Findings reveal that using the visual cues result in larger step lengths and faster walking times, and lead to a significant reduction in the number of freezing episodes and start hesitations experienced (Donovan et al., 2011; Kegelmeyer et al., 2013; Rahman et al., 2008; Van Gerpen et al., 2012). While these findings are promising, one limitation of this visual cueing approach is that standard protocol requires users to direct their attention downward towards the visual cue that is projected on the ground immediately in front of their feet. Directing vision towards the ground immediately ahead of oneself is potentially hazardous for three reasons. First, research has identified that when vision is limited to less than two step lengths ahead of someone as they walk, they are at a greater risk for colliding with obstacles (Matthis and Fajen, 2014; Patla, 1998). Second, because vision provides information regarding step-to-step progress, and is critical for accurate step placement, individuals may be less able to maintain dynamic balance during locomotion when vision is limited (Marigold and Patla, 2007; Patla, 1997). Third, directing visual gaze downwards towards the laser cue encourages individuals to adopt a forward flexed posture. This is important, especially for individuals with PD who already manifest a stooped posture and compromised postural reflexes that place them at an increased fall risk (Latt et al., 2009; Liu, 2009).

Taken together with research indicating that both using a walker (Cubo et al., 2003) and directing visual gaze less than two step lengths ahead (Matthis and Fajen, 2014) results in diminished spatial temporal parameters of gait, and with research illustrating that FoG may be exacerbated by decreased spatial temporal parameters of gait (Cubo et al., 2003); a logical next step in this line of inquiry is to determine

whether the efficacy of visual cueing is dependent upon the spatial location of cue presentation. Specifically, stemming from the research conducted by Patla (1998) and Marigold and Patla (2007), research is needed to determine whether visual cueing remains an effective strategy to improve gait among individuals with PD when the visual cue is directed ahead of the user instead of in the traditional spatial location at their feet.

As a first step in this process, initial feasibility testing is required. Therefore, the purpose of this study was to conduct a feasibility study to test study protocol and elucidate pragmatic indicators that will need to be considered in the design of a future full-scale study designed to investigate the spatial location of visual cue placement. Specifically, the objectives of this feasibility study were twofold: (i) test the study protocol and outcome metrics (i.e., effectiveness of recruitment strategy, visibility of visual cues, levels of protocol compliance); and (ii) determine whether there are preliminary indications that the intervention will be successful and thus worth pursuing (i.e., examine trends).

## **METHODS**

### ***Recruitment Strategy and Sample***

A convenience sample of 6 participants with idiopathic Parkinson's disease (PD), with a history of severe freezing of gait (FoG), were recruited for this study. Recruitment of participants and confirmation of PD diagnosis based on established diagnostic criteria (Hughes et al., 1992), were completed by a neurologist specializing in movement disorders.

In order to be eligible to participate, individuals were required to: (i) be at least 50 years of age, (ii) have a clinical diagnosis of PD with a history of FoG, (iii) be capable of walking 20 feet with or without the use of an assistive device, and (iv) have functional vision that allowed them to see the visual cue (laser beam of light projected on the ground). Individuals were excluded from participating if they reported experiencing major back or lower limb pathology that may influence gait, or if they were unable to perceive the visual cue.

### ***Testing Protocol***

Testing for each participant was completed in a single 45-min session held within a university based biomechanics gait laboratory. At the beginning of the testing session each participant received a copy of the letter of information to review, had all aspects of the study verbally explained to them, and were provided with an opportunity to ask any questions. Once all questions were answered to their satisfaction, participants were asked to provide informed written consent. The Health Sciences Research Ethics Board, at the University of Western Ontario, approved the research protocol, recruitment method, and mechanism for obtaining informed consent.

Upon providing informed consent, participants received a brief clinical examination by the study neurologist to determine disease severity. Specifically participants were assessed on the motor subscale (subsection III) of the Unified Parkinson's Disease Rating Scale (UPDRS-III; Movement Disorder Society Task Force

TABLE 1. Participant Demographics

Subject #	Sex	Age	Duration of Illness (years)	Medication	UPDRS III	Hoehn & Yahr	FOG-Q
1	M	86	13	Levodopa 1200 mg Comtan 800 mg	41	4	16
2	M	62	5	Levodopa 800 mg Entacapone 1200 mg	37	2.5	11
3	M	77	10	Levodopa 700 mg Entacapone 400 mg	31	3	16
4	M	77	18	Levodopa 2400 mg Entacapone 400 mg	47	4	22
5	F	83	10	Levodopa 800 mg	33	3	18
6	M	84	6	Levodopa 800 mg Ropinirole 4 mg	51	4	20

on Rating Scales for Parkinson's, 2003) and on the modified Hoehn & Yahr staging scale (H&Y; Goetz et al., 2004). Each participant was also asked to fill out a Freezing of Gait Questionnaire (FoG-Q; Giladi et al., 2000). The FoG-Q is a self-report survey consisting of six questions that subjectively assesses the severity and frequency of FoG. For each question the respondent is asked to assign a value of 0 to 4 regarding different aspects of FoG or gait disturbance. The cumulative total of these values range from 0 to 24, with a higher overall score corresponding to more severe FoG. This questionnaire has been shown to have excellent intra-rater reliability (ICC = 0.84; Nieuwboer et al., 2007), and excellent test-retest reliability ( $r = 0.84$ ; Giladi et al., 2009) in people with PD. Participants' demographics are presented in Table 1.

To ensure participant safety, each participant was placed in a balance support harness system (SoloStep™) consisting of a support vest attached to an overhead rail. To ensure a proper fit and to help participants become accustomed to the harness system, participants walked to the end of the room, turned, and walk back (approximately 20 feet). Next, participants completed a series of 12 videotaped walking trials using a wheeled walker instrumented with a laser cueing device (i.e., Mobilaser; Figure 1). Specifically participants were asked to complete 3 walking trials under each of the following four conditions: (i) no visual cue (baseline), (ii) visual cue projected between the center of the rear wheels of the walker (traditional cue placement), (iii) visual cue projected at a distance equivalent to mean sex specific step length (male = 62 cm, female = 60 cm; Ko et al., 2011) in front of the center of the rear wheels (step length), and (iv) visual cue projected at a distance equivalent to mean sex-specific stride length (male = 123 cm, female = 119 cm; Ko et al., 2011) in front of the center of the rear wheels (stride length). Each walking trial followed the protocol of the Timed Up & Go test (TUG) as follows. Participants started in a seated position in a standard arm chair (seat height = 45 cm), and when instructed to begin, stood up, walked 3 meters at a comfortable pace, turned around, walked back to the chair and sat down. The time it took participants to complete the trial was recorded using an Adanac 3000® digital stopwatch.

Immediately prior to the beginning of each trial, the participant's received the following instruction: 'When I say go, I would like you to stand up, walk at a

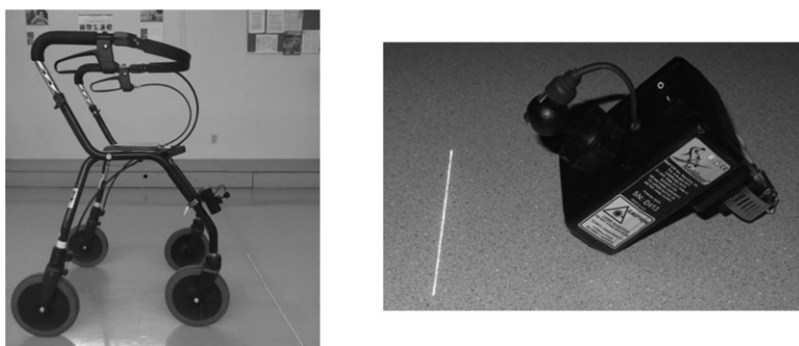


FIGURE 1. Mobilaser—visual cueing device.

comfortable pace to the end of the mat, turn around, walk back, and sit down.’ For trials where the visual cue was located between the walker rear wheels (traditional cue placement), participants also received the verbal instruction ‘As you walk I would like you to focus on *stepping over the laser cue.*’ For trials where the visual cue was located ahead of the walker rear wheels (i.e., either step length, or stride length conditions), participants received the verbal instruction ‘As you walk I would like you to focus on *stepping towards the laser cue.*’ To ensure participants understood the instructions, a single practice trial was completed for each condition at the beginning of each block of walking trials. To avoid practice effects, the order of presentation of the walking conditions was randomized for each participant.

All testing was completed while participants were on their self-determined peak, or ‘on’ phase, of their medication cycle. To help ensure all participants were within their ‘on’ phase, testing was conducted approximately two hours after participants had taken their usual dosage.

## **Outcome Measures**

### *Spatial Temporal Parameters of Gait*

Spatiotemporal parameters of gait for each walking trial were acquired using a 4 foot wide  $\times$  10 foot long Zeno Electronic Walkway<sup>®</sup> Model Z4 $\times$ 10 and ProtoKinetics Movement Analysis Software (PKMAS) (Zenometrics LLC, Peekskill, NY, USA). Using sensor array technology, the Zeno walkway<sup>®</sup> samples gait at 120 Hz and has a spatial resolution accuracy of 1.27 cm and temporal resolution accuracy of 1 sample (ProtoKinetics Movement Analysis Software, 2012). The Zeno walkway<sup>®</sup> (formerly GaitRite) has been found to be a reliable measurement of gait parameters in this population (Chien et al., 2006; Egerton et al., 2014). The dependent variables included: velocity, step length, and the time taken to complete the 180° turn at the end of the walkway. Trials were averaged within each condition such that a single value was obtained for each outcome measure.

### *Timed Up and Go (TUG)*

Functional mobility was assessed as participants completed each walking trial via the Timed-Up-And-Go (TUG) testing protocol under each condition. This test has

been shown to have good test–retest reliability ( $r = 0.80$ ; Huang et al., 2011), and high inter-rater reliability ( $ICC \geq 0.87$ ; Morris et al., 2001) in people with PD.

### *Walker Positioning*

To determine if the position of the walker in relation to the participant changed as a result of the spatial location of the visual cue presentation, all walking trials were videotaped using a Canon PowerShot SX 220 HS camera and analyzed using Kinovea (version 0.8.15) software. Two reflective markers (A & B) were placed in parallel on the walker frame and one reflective marker (C) placed on the balance harness positioned over the lateral aspect of the participants' iliac crest. Using Kinovea, a vertical line was drawn between markers A and B and a horizontal line drawn at a right angle from the vertical line to marker C. The horizontal distance between the vertical line (walker) and marker C (participant) was used to determine the relative position of the walker in relation to the participant.

## **RESULTS**

### ***Objective I—Methodological Feasibility***

#### *Recruitment Strategy*

Participants were recruited from a single neurological practice over a 2 month time-frame. In total, seven individuals agreed to participate; however, one of these individuals did not meet the inclusion criteria and was therefore excluded. The six participants recruited were highly varied across numerous demographic characteristics (Table 1). Although this recruitment strategy served the purpose of this current study, for the purpose of designing a future large scale study it would likely be advisable to expand recruitment efforts to include multiple clinics and involve national organizations such as the Parkinson Society Canada or the National Parkinson Foundation.

#### *Protocol Compliance*

With altering the spatial location of the visual cue, it was unknown as to whether the intensity of the visual stimulus would be strong enough for participants to clearly see the cue when projected ahead of the walker. All participants indicated that they were able to clearly observe the visual cue even when it was directed to the furthest position away from the walker, equivalent to the average stride length of an older adult (119–123 cm).

With respect to trial completion, the majority of participants (4/6) were able to complete all aspects of testing procedures. Two participants (P4, P6) were unable to complete the testing protocol in its entirety. Both of these individuals experienced fatigue near the end of some of the trials and required adjustments to be made to the position of the chair to complete the final turn of the walking trials. This was most evident with participant 4 who experienced severe fatigue as a result of extended periods of freezing. Secondary to fatigue, the participant was unable to complete all 12 trials and the decision was made to have the participant subsequently complete only a single trial of each visual cue condition. Based on the performance of these



participants the original testing protocol may be too challenging for individuals with severe FoG to complete.

Each testing session lasted 30–45 min within the lab, which included obtaining informed consent, and trial demonstrations provided by the researchers. Due to the relatively short length of the testing session, participants did not report experiencing any issues with wearing off their medication over the course of the session.

Lastly, all participants were able to independently complete the FoG-Q. This is important in terms of a future home based longitudinal protocol, as the FoG-Q can be used as a measure of change that can be collected without a researcher's or clinician's presence.

### ***Objective II—Preliminary Findings (Effectiveness of Cue at Different Spatial Locations)***

To determine whether the intervention shows promise as an effective management strategy, comparisons were made between values obtained at baseline (no visual cue) to those reported during each presentation of the visual cue (baseline vs. traditional cue; baseline vs. step length; and baseline vs. stride length).

#### ***Spatial Temporal Parameters of Gait***

There were no significant differences in step length at baseline ( $M = 30.67$ ,  $SD = 13.98$ ) compared to when visual cues were presented in each of the visual cue locations: traditional cue placement [ $M = 38.50$ ,  $SD = 14.27$ ,  $t(5) = -2.159$ ,  $p = 0.083$ ], step length cue placement [ $M = 35.33$ ,  $SD = 17.85$ ,  $t(5) = -1.075$ ,  $p = 0.331$ ], or stride length cue placement [ $M = 34.17$ ,  $SD = 18.02$ ,  $t(5) = -1.069$ ,  $p = 0.334$ ]. Similar findings were also identified for velocity as there were no significant differences detected between baseline ( $M = 51.17$ ,  $SD = 28.91$ ) and each of the visual cue locations: traditional cue placement [ $M = 48.50$ ,  $SD = 8.63$ ,  $t(5) = 0.392$ ,  $p = 0.711$ ], step length cue placement [ $M = 51.33$ ,  $SD = 32.02$ ,  $t(5) = -0.027$ ,  $p = 0.980$ ], or stride length cue placement [ $M = 51.67$ ,  $SD = 31.98$ ,  $t(5) = -0.088$ ,  $p = 0.933$ ]. Similar to the findings reported for step length and velocity, no significant differences were identified between the length of time it took participants to turn in the absence of a visual cue ( $M = 20.17$ ,  $SD = 25.96$ ) compared to when they used a visual cue irrespective of cue location: traditional cue placement [ $M = 7.83$ ,  $SD = 3.71$ ,  $t(5) = 1.312$ ,  $p = 0.246$ ], step length cue placement [ $M = 12.67$ ,  $SD = 14.35$ ,  $t(5) = 0.802$ ,  $p = 0.459$ ], or stride length cue placement [ $M = 15.17$ ,  $SD = 16.53$ ,  $t(5) = 0.722$ ,  $p = 0.503$ ].

Although results for each of the variables were statistically nonsignificant, results suggest the presentation of visual cues did have an impact on spatiotemporal parameters of gait for the majority of participants. For example, with the Mobilaser turned on, 5 of 6 participants demonstrated increases to step length, and 3 of 6 participants demonstrated increases to velocity and decreases to turn time. It is important to note that despite there being an overall trend for the visual cue to evoke improvements to gait, there was no consistent pattern delineating which of the visual cueing spatial locations was most effective across each of the dependent variables.

### **TUG Test**

Similar to the findings reported for the spatiotemporal parameters of gait, there were no significant differences between the time it took participants to complete the TUG test at baseline ( $M = 67.83$ ,  $SD = 77.58$ ) compared to when visual cues were presented in the following spatial locations: traditional cue placement [ $M = 40.17$ ,  $SD = 21.01$ ,  $t(5) = 1.127$ ,  $p = 0.311$ ], step length cue placement [ $M = 48.00$ ,  $SD = 33.18$ ,  $t(5) = 0.827$ ,  $p = 0.446$ ], or stride length cue placement [ $M = 49.33$ ,  $SD = 36.95$ ,  $t(5) = 0.966$ ,  $p = 0.378$ ]. Again, although results were statistically non-significant, some participants substantially improved their test scores while using a visual cue. The most prominent example of this occurrence was illustrated by participant 4 who without the use of the visual cue took over 3.5 min to complete a single trial, whereas with the visual cue their gait improved such that their best trial was completed in just over 1 min.

### **Walker Positioning**

To determine whether the use of the visual cueing strategies altered the way participants positioned their walkers in relation to their body, comparisons in distance between the anterior superior iliac spine (ASIS) of the participants and their walker frame were made between baseline and each level of the visual cue. In contrast to the aforementioned nonsignificant results reported for spatiotemporal parameters of gait and the TUG test, significant differences in walker positioning were identified between baseline and each of the cueing positions: traditional cue position [ $t(5) = 3.38$ ,  $p = 0.02$ ], step length cue position [ $t(5) = 5.395$ ,  $p = 0.003$ ], and stride length cue position [ $t(5) = 4.941$ ,  $p = 0.004$ ]. The means and standard deviations, along with individual participant data for the distance between walker and the ASIS of each participant are presented in Table 2. These results suggest that regardless of the spatial location of the visual cue, participants positioned themselves closer to their walker during trials wherein the Mobilaser was turned on in comparison to when they ambulated in the absence of a visual cue. Interestingly from the video analysis the observation was made that during baseline 4 participants (P2, P4, P5, P6) were using the walker incorrectly (operationalized as their footsteps fell outside of the walker frame), whereas with the Mobilaser turned on, regardless of cue location, each participant's footsteps either fell within the walker frame or at minimum were aligned with the walkers back wheels.

## **DISCUSSION**

This study set out to achieve two main objectives. The first objective was to evaluate the feasibility of a novel study design using the Mobilaser visual cueing device in participants with PD and severe FoG. The study was found to be feasible, although a number of important issues should be highlighted to guide future research in this area. The second objective was to determine if preliminary evidence exists to suggest a full-scale study be conducted to evaluate the effectiveness of various placements of a visual cue in improving parameters of gait in individuals with PD and severe FoG. Although the majority of findings related to gait parameters were non-significant, there were clear trends that warrant further investigation.

**TABLE 2. Walker Positioning—Average Distance Between Participants Left Hip and the Walker (cm) Across Trials for Each Condition of the Visual Cue**

	Participant	Baseline	Traditional Cue	Step Length Cue	Stride Length Cue
Distance (cm)	1	57	50	42	45
	2	57	36	43	45
	3	42	43	40	42
	4	40	29	24	29
	5	56	45	35	43
	6	71	50	54	60
	Mean	54	42	40	44
	SD	11	8	10	10

### ***Objective I—Methodological Feasibility***

#### *Recruitment Strategy*

Participants, with PD and severe FoG, were recruited from a single clinical neurology practice of approximately 400 patients with PD. Based on previous recruitment efforts from this neurological practice it was assumed that recruitment would not be an issue; however, it was quickly realized that participants with severe FoG were often too impaired to meet inclusion criteria or were too disabled to participate in a trial of 40-min duration. Conversely, patients with milder FoG impairments did not wish to participate in a study that utilized a walker, as they were ambulating free of gait aids. In the end, only seven participants were recruited over the two months, with one excluded for new onset vision problems, leaving only six individuals to participate in the study. Of the remaining six participants, two were unable to complete the entire protocol due to fatigue.

Given these findings, future studies would likely benefit from modifications to the recruitment pool and modifications to the inclusion criteria. Expanding recruitment to include multiple neurological practices, or utilizing community based national organizations, such as the Parkinson Society Canada or National Parkinson Foundation, would yield a larger population base to draw upon, and should increase the number of appropriate subjects. Furthermore, consideration of broader inclusion criteria to include participants with a variety of gait impairments, including individuals who only experience occasional FoG, may help with recruitment efforts and study completion.

#### *Mobilaser attachment and cue perception*

It was found that the Mobilaser was easily secured to the participants individualized walker frames, and that the articulating head allowed for the correct positioning of the laser light. Despite these findings, the issue remains that many individuals with PD do not use walkers or canes in their day to day life. Identifying novel ways to use the Mobilaser, such as attaching it to a belt clip or an urban walking pole is an important future consideration as this will help to increase the generalizability of the Mobilaser device to individuals who do not utilize mobility aids but may benefit from this management strategy.

During the study design, it was postulated that the participants might have difficulty seeing the laser light, particularly when placed at a distance in front of the walker. In the laboratory setting participants reported no difficulties seeing the laser projection, regardless of the position of the light. While this was an positive finding, it is impossible to know for sure how this will translate to different environments, such as outdoors, or in brightly lit indoor spaces. Future studies are needed to evaluate the visibility in various environments.

### *Protocol Compliance*

The testing protocol lasted 30 to 45 min with breaks as needed. It was anticipated that this would be sufficient for this population; however, two participants were not able to complete all the trials due to extreme fatigue and worsening FoG. Contrary to previously reported studies, these results suggest that the study protocol in its current form, of 12 walking trials, may be too demanding for this population. Originally, this study duration and number of trials were based on a previous study by Jiang and Norman (2006) that examined cueing among a sample of individuals with PD and FoG, and therefore was determined to be a reasonable expectation of our participants. Two reasons why participants in our study may have experienced difficulty with completing the study as originally designed may be related to the severity of the disease of enrolled participants, and the increased physical demands associated with completing the TUG. The participants in our study had advanced PD and experienced severe FoG throughout most of the day, both of which are associated with worsening fatigue and a large burden of disease (Bloem et al., 2004; Rahman et al., 2008). In comparison, the participants in the study by Jiang and Norman, (2006) had less severe FoG and a milder burden of disease. Another reason for the increased difficulty of our participants may have been the study protocol. The protocol used in the current study included the TUG test which involves standing from a chair, initiating gait, turning twice, and backing up to sit down again. All of these activities are known to trigger or worsen FoG and ultimately may have been too physically demanding for our participants (Morris et al., 2008). This protocol was not used by Jiang and Norman, (2006) which may explain why their participants were better able to tolerate the testing protocol. In future studies, individuals with less severe FoG could be studied to increase compliance with the existing protocol. Alternatively, instead of completing the TUG test, the protocol could be changed to only involve straight walking trials, thereby minimizing the physical exertion required by participants.

Stressful environments are a known trigger of FoG (Contreras and Grandas, 2012; Lamberti et al., 1997; Rahman et al., 2008), and it was anticipated that the participants' potential degree of stress in the study would be minimal. To minimize the amount of stress/anxiety experienced by participants, each individual was provided with an opportunity to walk around the lab and acclimatize to the testing setup. Despite this opportunity, one participant reported that he felt anxiety during the first half of the testing session due to concerns that he was not meeting the expectations of the research team. When this issue was identified, the participant was provided with positive reinforcement and he became more relaxed and wished to continue with the study. In future studies, more time to acclimatize participants to the environment would be beneficial to reduce the impact of stress on participant

performance. In addition, the undertaking of a longitudinal study could acclimatize participants to the visual cueing technique and hopefully reduce their anxiety during the testing phase.

### ***Objective II—Preliminary Findings Effectiveness of Cue at Different Spatial Locations***

The second objective of this study was to determine whether there are preliminary indications that presenting the visual cue in nontraditional locations could lead to improvements in gait parameters thus suggesting this line of inquiry is appropriate for further study. While the majority of improvements identified among the spatiotemporal parameters of gait did not reach statistical significance, there were trends to suggest that further investigation is warranted. For example, while the traditional cue was found to be the most effective cue in terms of increasing step length, and minimizing the time required for participants to turn 180 degrees, the cue presented at step length was observed to be most effective at improving walker positioning (i.e., minimizing the distance between participant and walker). Having the ability to influence the manner in which participants position their walker is an important clinical consideration as previous research that evaluated the use of rolling walkers by older adults indicated that 50% of participants assumed a forward leaning posture during walker use (Liu, 2009). As a result of the posture adopted, the user's feet did not maintain a safe position between the rear wheels of the walker, thus increasing the risk of a fall (Liu, 2009). Therefore while rolling walkers are designed to provide support to help with balance and minimize falls risk, if not used properly, they may exacerbate falls. Consistent with these previous literature findings, the current study demonstrated that during the baseline condition, 4 of 6 participants adopted a forward leaning posture and did not walk within the walker frame. However, with the assistance of the Mobilaser, all participants significantly decreased the distance between themselves and the walker and safely walked within the walker frame, thus decreasing the potential for falls. Although it is unclear why participants adopted a safer position in relation to the walker when using the visual cues, one possibility could be that by focusing attention on the visual cues participants were more aware of their body positioning with regards to the walker.

Another important clinical consideration to note is that while the traditional cue placement was found to lead to a reduction in velocity as participants walked in a straight line, the cues positioned at both step length and stride length did not lead to similar reductions, but rather maintained and/or slightly increased velocity. These findings coupled with the aforementioned results suggest that by presenting the visual cues in different locations it may be possible for clinicians to target improvements to specific parameters of gait based upon individualized client need. For example, for a client with PD who presents with a rapid shuffling gait (festination), a clinician may select the traditional cue placement to assist with improving step length while simultaneously reducing velocity, whereas for a client who ambulates with the walker too far in front, a cue directed at the step length position may serve to best correct this behavior. These modality-specific findings are consistent with the results presented by Suteerawattananon (2004) wherein visual and

auditory cues were found to improve gait performance among individuals with PD in different ways. Specifically, improvements in cadence were found to be facilitated to a greater extent by auditory cues, whereas improvements to stride length were found to be facilitated to a greater extent by visual cues. Similar findings were also reported by Rahman et al., (2008) who identified differential findings between cueing modalities wherein 31.5% of their sample improved mobility with use of the visual cues and a lesser percent expressed similar benefits through tactile and auditory cues.

With the potential ability to tailor the intervention to address the specific needs of each client, manipulating the spatial presentation of visual cues shows promise as a strategy to help individuals manage gait disturbances that otherwise might contribute to a decrease in participation in social activities and activities of daily living (Gschwind et al., 2010). For example, not only does this cueing approach have the potential to directly benefit mobility by way of improvements to spatial temporal parameters of gait (i.e., velocity & step length), these improvements, along with enhanced walker positioning, may positively impact mobility by enhancing ones sense of control and confidence in relation to their mobility. As confirmed by the performance of participant 4, with a reassured sense of self-confidence, individuals will be less likely to experience apprehension/anxiety that is known to negatively impact gait (Nuti et al., 2004). Subsequently, armed with an enhanced sense of control and improved mobility, it is likely that individuals would be better positioned to engage in activities that are meaningful and bring purpose to their lives, thereby improving their quality of life.

Finally, while the results of this study are promising, it is important to note that owing to a small number of participants ( $N = 6$ ) the analyses have limited statistical power. As such, caution should be taken when interpreting the findings, and restraint used when implementing the results, as generalizability will be limited.

### **CONCLUSION**

The results of this study suggest that three modifications could be made to the study protocol to better capture the influence of manipulating spatial location of visual cue placement. The first modification entails expanding recruitment efforts to include individuals with less severe FoG and to recruit from a larger sample base as to increase participant enrolment and statistical power. The second modification would be to revise the testing protocol to include only straight line walking tasks wherein participants begin and end each trial in an upright standing position as to reduce fatigue and increase compliance with the testing protocol. The third and final suggested modification would be to provide participants with additional time to become acclimatized to the study protocol, and to ensure ongoing positive feedback is provided throughout the testing session as to minimize stress, and reduce the impact of anxiety such that a more accurate representation of participants best gait performance can be established. The results of this study also indicate that the preliminary spatiotemporal gait findings are sufficient to recommend that a future larger scale study that incorporates the aforementioned protocol modifications be undertaken. Moreover, additional research is also warranted to (a) determine the individualized characteristics that may predict where the optimal visual cue

location is for each specific user, and (b) to examine the efficacy of the intervention in a naturalistic setting over a longitudinal time period.

### **DECLARATION OF INTEREST**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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### **REFERENCES**

- Balash Y, Peretz C, Leibovich G, Herman T, Hausdorff JM, Giladi N. (2005). Falls in outpatients with Parkinson's disease: frequency, impact and identifying factors. *Journal of Neurology* 252(11):1310–1315. doi: 10.1007/s00415-005-0855-3
- Benatru I, Vaugoyeau M, Azulay JP. (2008). Postural disorders in Parkinson's disease. *Clinical Neurophysiology* 38(6):459–465. doi: 10.1016/j.neucli.2008.07.006
- Blin O, Ferrandez AM, Serratrice G. (1990). Quantitative analysis of gait in Parkinson patients: increased variability of stride length. *Journal of the Neurological Sciences* 98(1):91–97.
- Bloem BR, Hausdorff JM, Visser JE, Giladi N. (2004). Falls and freezing of gait in Parkinson's disease: a review of two interconnected, episodic phenomena. *Movement Disorders* 19(8):871–884. doi: 10.1002/mds.20115
- Bloem BR. (1992). Postural instability in Parkinson's disease. *Clinical Neurology and Neurosurgery* 94(Suppl)S41–45.
- Chien SL, Lin SZ, Liang CC, Soong YS, Lin SH, Hsin YL, et al. (2006). The efficacy of quantitative gait analysis by the GAITRite system in evaluation of Parkinsonian bradykinesia. *Parkinsonism & Related Disorders* 12(7):438–442. doi: 10.1016/j.parkreldis.2006.04.004
- Contreras A, Grandas F. (2012). Risk factors for freezing of gait in Parkinson's disease. *Journal of the Neurological Sciences* 320(1-2):66–71. doi: 10.1016/j.jns.2012.06.018
- Cubo E, Moore CG, Leurgans S, & Goetz CG. (2003). Wheeled and standard walkers in Parkinson's disease patients with gait freezing. *Parkinsonism & Related Disorders* 10(1):9–14.
- Donovan S, Lim C, Diaz N, Browner N, Rose P, Sudarsky LR, et al. (2011). Laserlight cues for gait freezing in Parkinson's disease: an open-label study. *Parkinsonism & Related Disorders* 17(4):240–245. doi: 10.1016/j.parkreldis.2010.08.010
- Egerton T, Thingstad P, Helbostad JL. (2014). Comparison of programs for determining temporal-spatial gait variables from instrumented walkway data: PKmas versus GAITRite. *BMC Res Notes* 7:542. doi: 10.1186/1756-0500-7-542
- Giladi N, Kao R, Fahn S. (1997). Freezing phenomenon in patients with Parkinsonian syndromes. *Movement Disorders* 12(3):302–305. doi: 10.1002/mds.870120307
- Giladi N, Shabtai H, Simon ES, Biran S, Tal J, & Korczyn AD. (2000). Construction of freezing of gait questionnaire for patients with Parkinsonism. *Parkinsonism & Related Disorders* 6(3):165–170.
- Giladi N, Tal J, Azulay T, Rascol O, Brooks DJ, Melamed E, et al. (2009). Validation of the freezing of gait questionnaire in patients with Parkinson's disease. *Movement Disorders* 24(5):655–661. doi: 10.1002/mds.21745
- Giladi N, Treves TA, Simon ES, Shabtai H, Orlov Y, Kandinov B, et al. (2001). Freezing of gait in patients with advanced Parkinson's disease. *Journal of Neural Transmission* 108(1):53–61.
- Glickstein M, Stein J. (1991). Paradoxical movement in Parkinson's disease. *Trends in Neurosciences* 14(11):480–482.
- Goetz CG, Poewe W, Rascol O, Sampaio C, Stebbins GT, Counsell C, et al. (2004). Movement disorder society task force report on the hoehn and yahr staging scale: status and recommendations. *Movement Disorders* 19(9):1020–1028. doi: 10.1002/mds.20213

- Gray P, Hildebrand K. (2000). Fall risk factors in Parkinson's disease. *Journal of Neuroscience Nursing* 32(4):222–228.
- Grimbergen YA, Munneke M, Bloem BR. (2004). Falls in Parkinson's disease. *Current Opinion in Neurology* 17(4):405–415.
- Gschwind, Yves J, Bridenbaugh, Stephanie A, Kressig, Reto W. (2010). Gait disorders and falls. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry* 23(1):21–32. doi: 10.1024/1662-9647/a000004
- Huang SL, Hsieh CL, Wu RM, Tai CH, Lin CH, Lu WS. (2011). Minimal detectable change of the timed “up & go” test and the dynamic gait index in people with Parkinson disease. *Physical Therapy* 91(1):114–121. doi: 10.2522/ptj.20090126
- Hughes AJ, Daniel SE, Kilford L, Lees AJ. (1992). Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinico-pathological study of 100 cases. *Journal of Neurology, Neurosurgery & Psychiatry* 55(3):181–184.
- Jenkins ME, Almeida QJ, Spaulding SJ, van Oostveen RB, Holmes JD, Johnson AM, Perry SD. (2009). Plantar cutaneous sensory stimulation improves single-limb support time, and EMG activation patterns among individuals with Parkinson's disease. *Parkinsonism & Related Disorders* 15(9):697–702. doi: 10.1016/j.parkreldis.2009.04.004
- Jiang Y, Norman KE. (2006). Effects of visual and auditory cues on gait initiation in people with Parkinson's disease. *Clin Rehabil* 20(1):36–45.
- Kegelmeyer DA, Parthasarathy S, Kostyk SK, White SE, Kloos AD. (2013). Assistive devices alter gait patterns in Parkinson disease: advantages of the four-wheeled walker. *Gait Posture* 38(1):20–24. doi: 10.1016/j.gaitpost.2012.10.027
- Ko SU, Tolea MI, Hausdorff JM, & Ferrucci L. (2011). Sex-specific differences in gait patterns of healthy older adults: results from the Baltimore Longitudinal Study of Aging. *Journal of Biomechanics* 44(10):1974–1979. doi: 10.1016/j.jbiomech.2011.05.005
- Lamberti P, Armenise S, Castaldo V, de Mari M, Iliceto G, Tronci P, & Serlenga L. (1997). Freezing gait in Parkinson's disease. *European Neurology* 38(4):297–301.
- Latt MD, Lord SR, Morris JG, & Fung VS. (2009). Clinical and physiological assessments for elucidating falls risk in Parkinson's disease. *Movement Disorders* 24(9):1280–1289. doi: 10.1002/mds.22561
- Lindholm B, Hagell P, Hansson O, Nilsson MH. (2014). Factors associated with fear of falling in people with Parkinson's disease. *BMC Neurology* 14:19. doi: 10.1186/1471-2377-14-19
- Liu HH. (2009). Assessment of rolling walkers used by older adults in senior-living communities. *Geriatrics & Gerontology International* 9(2):124–130. doi: 10.1111/j.1447-0594.2008.00497.x
- Marigold DS, Patla AE. (2007). Gaze fixation patterns for negotiating complex ground terrain. *Neuroscience* 144(1):302–313. doi: 10.1016/j.neuroscience.2006.09.006
- Matthis JS, Fajen BR. (2014). Visual control of foot placement when walking over complex terrain. *Journal of Experimental Psychology: Human Perception and Performance* 40(1):106–115. doi: 10.1037/a0033101
- Moore O, Peretz C, Giladi N. (2007). Freezing of gait affects quality of life of peoples with Parkinson's disease beyond its relationships with mobility and gait. *Movement Disorders* 22(15):2192–2195. doi: 10.1002/mds.21659
- Morris ME, Ianksek R, Galna B. (2008). Gait festination and freezing in Parkinson's disease: pathogenesis and rehabilitation. *Movement Disorders* 23(Suppl 2):S451–460. doi: 10.1002/mds.21974
- Morris ME, Ianksek R, Matyas TA, Summers JJ. (1996). Stride length regulation in Parkinson's disease. Normalization strategies and underlying mechanisms. *Brain* 119(Pt 2): 551–568.
- Morris S, Morris ME, & Ianksek R. (2001). Reliability of measurements obtained with the Timed “Up & Go” test in people with Parkinson disease. *Physical Therapy* 81(2):810–818.
- Movement Disorder Society Task Force on Rating Scales for Parkinson's, Disease. (2003). The unified Parkinson's disease rating scale (UPDRS): status and recommendations. *Movement Disorders* 18(7):738–750. doi: 10.1002/mds.10473
- Nieuwboer A, Kwakkel G, Rochester L, Jones D, van Wegen E, Willems AM, et al. (2007). Cueing training in the home improves gait-related mobility in Parkinson's disease: the



- RESCUE trial. *Journal of Neurology, Neurosurgery & Psychiatry* 78(2):134–140. doi: 10.1136/jnnp.200X.097923
- Nombela C, Hughes LE, Owen AM, Grahn JA. (2013). Into the groove: can rhythm influence Parkinson's disease? *Neuroscience & Biobehavioral Reviews* 37(10 Pt 2):2564–2570. doi: 10.1016/j.neubiorev.2013.08.003
- Novak P, Novak V. (2006). Effect of step-synchronized vibration stimulation of soles on gait in Parkinson's disease: a pilot study. *Journal of Neuroengineering and Rehabilitation* 3:9. doi: 10.1186/1743-0003-3-9
- Nuti A, Ceravolo R, Piccinni A, Dell'Agnello G, Bellini G, Gambaccini G, ... Bonuccelli U. (2004). Psychiatric comorbidity in a population of Parkinson's disease patients. *European Journal of Neurology* 11(5):315–320. doi: 10.1111/j.1468-1331.2004.00781.x
- Nutt JG, Bloem BR, Giladi N, Hallett M, Horak FB, & Nieuwboer A. (2011). Freezing of gait: moving forward on a mysterious clinical phenomenon. *The Lancet Neurology* 10(8):734–744. doi: 10.1016/S1474-4422(11)70143-0
- Patla A. (1997). Understanding the roles of vision in the control of human locomotion. *Gait Posture* 5(1):54–69.
- Patla A. (1998). How is Human Gait Controlled by Vision. *Ecological Psychology* 10(3):287–302.
- Rahman S, Griffin HJ, Quinn NP, Jahanshahi M. (2008). The factors that induce or overcome freezing of gait in Parkinson's disease. *Behavioural Neurology* 19(3):127–136.
- Rochester L, Hetherington V, Jones D, Nieuwboer A, Willems AM, Kwakkel G, Van Wegen E. (2005). The effect of external rhythmic cues (auditory and visual) on walking during a functional task in homes of people with Parkinson's disease. *Archives of Physical Medicine and Rehabilitation* 86(5):999–1006. doi: 10.1016/j.apmr.2004.10.040
- Spildooren J, Vercrusse S, Meyns P, Vandenbossche J, Heremans E, Desloovere K, et al. (2012). Turning and unilateral cueing in Parkinson's disease patients with and without freezing of gait. *Neuroscience* 207:298–306. doi: 10.1016/j.neuroscience.2012.01.024
- Suteerawattananon M, Morris GS, Etnyre BR, Jankovic J, Protas EJ. (2004). Effects of visual and auditory cues on gait in individuals with Parkinson's disease. *Journal of the Neurological Sciences* 219(1-2):63–69. doi: 10.1016/j.jns.2003.12.007
- Van Gerpen JA, Rucker CT, Matthews M, Saucier MA. (2012). Lifting the "FOG" with laser generated visual-cueing. *Neurologist* 18(5):298–301. doi: 10.1097/NRL.0b013e318266f919
- Wielinski CL, Erickson-Davis C, Wichmann R, Walde-Douglas M, Parashos SA. (2005). Falls and injuries resulting from falls among patients with Parkinson's disease and other parkinsonian syndromes. *Movement Disorders* 20(4):410–415. doi: 10.1002/mds.20347