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A PILOT STUDY: INFLUENCE OF VISUAL CUE COLOR ON FREEZING OF GAIT IN PERSONS WITH PARKINSON'S DISEASE

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Abstract

Purpose—To investigate the effect of red and green light beams on gait and freezing of gait (FOG) in persons with Parkinson's disease (PD).

Methods—Seven persons with PD who experienced FOG participated in the study. Gait and turning performances were studied while walking with canes with red, green, and no light beams while 'off' and 'on' anti-parkinsonian medications. Gait speed, cadence, and stride were recorded. Time and number of freezing episodes were recorded during a 50-foot walk and a 360° turn.

Results—During "off" medication, compared to no light, stride length improved when using the green light, but not the red. During the 50-foot walk, freezing episodes were reduced when using the green light compared to both the red and no light. During the 360° turn, time, number of steps, and number of freezing episodes were reduced using the green light compared to the red and no light. During 'on' medication, gait speed and stride length improved more with the green light compared to the red. Neither color showed any effect on cadence during either medication state.

Conclusion—A green light improved gait and alleviate FOG in persons with PD better than a red light or no light.

Keywords

Parkinson's disease; Freezing of Gait; Visual Cue; Color

Introduction

Freezing of gait (FOG) is one of the common gait disturbances found in patients with advanced Parkinson's disease (PD). Freezing refers to transient episodes, usually lasting seconds, in which initiation or continuation of walking is halted. FOG is one of the most

disabling symptoms of PD [1] and usually does not respond to dopaminergic therapy [2]. Based on responses to a questionnaire by 6,620 patients, 47% reported experiencing FOG [3]. Freezing on turning was reported by 45% of a sample of 990 people with PD [4].

In advanced stages of PD, the combination of the progression of the disease and the long exposure to anti-parkinsonian medications causes more frequent FOG [5; 6]. The most common form of FOG is initiation hesitation, which is observed when the patient attempts to lift a leg and to begin walking. Other common tasks associated with FOG are making a turn and walking through a narrow area such as a doorway or an elevator [6].

FOG has been known to respond favorably to bright visual cues (e.g. a walking stick with laser beam, transverse lines on the floor, colored objects, colored floor tiles,) [7; 8; 9]. Yellow [10; 11] and white floor markers [12; 13] were the only two colors reported in the literature to improve gait in persons with PD. However, there is no evidence regarding the comparison of the benefit of different light colors on gait or FOG. Walking devices such as canes and wheeled walkers with red light cues are available commercially for patients with PD. Red and green light beams are commonly used as pointers during presentations, thus are easily available. Therefore, we selected red and green lights because they were affordable and could be attached to a cane as a portable visual light cue.

In this pilot study, red and green light beams were attached to canes (Figure 1) for walking and turning performed during both 'off' and 'on' anti-parkinsonian medication states. We used turning because it is a strong provocative task for FOG. Both 'off' and 'on' medication states were studied to ensure the provocation of FOG. Schaafsma et al. reported that 95% of persons with PD experienced freezing during turning while 'off' medication, compared to 32% while 'on' medication [14]. We compared gait characteristics, turning performance and freezing episodes while using canes with no, red, and green light beams.

Methods

Subjects

Seven subjects (6 males and one female) with PD participated in the study. All subjects experienced FOG, which was rated as at least a 2 (occasional freezing) on item 14 (freezing when walking) of the Unified Parkinson's Disease Rating Scale (UPDRS) [15]. All participants usually received anti-parkinsonian medications (Levodopa/Carbidopa [n = 7], Requip [n = 1], Amantadine [n = 3], and Mirapex [2]). Six subjects usually ambulated with a cane. One subject used a wheeled walker on a regular basis; however, he was able to perform the tests using a cane.

Procedures

Each subject received an explanation of all procedures and read and signed a consent form approved by the Institutional Review Boards of XXX College of Medicine. A brief medical history, demographic information (gender, age, height, and weight), disease duration, disability stage [16], and UPDRS scores while 'off' and 'on' medication were obtained from the subjects' reports and/or their medical records. The Freezing of Gait questionnaire (FOG-Q) was used to rate the participants' freezing problems [17].

Three canes were used during testing; one with no light beam, one with a red light, and one with a green light. Cane lengths were adjusted so that a subject's elbow was at approximately 30 degrees flexion to prevent gait change due to improper cane length. Subjects were instructed to practice walking with a lighted cane as a visual cue prior to data collection to minimize hesitancy in using a new device.

All tests were performed while the subjects were 'off' and then 'on' their anti-parkinsonian medications. For 'off' medication testing, the subjects were instructed to take the last dose of anti-parkinsonian medications the night before the testing date and come to the laboratory the following morning without taking any anti-parkinsonian medications. In each of the three light conditions (no, red, and green light beam), the following activities were performed in the gait laboratory: 1) walking on an electronic walkway (GAITRite, CIR Systems Inc., Havertown, PA) [18]; 2) walking 50 feet; and 3) turning 360 degrees. Subjects were asked to perform all tasks at their self-selected speed. For the 50-foot walk test, subjects were asked to walk 25 feet, turn, and walk back 25 feet. The order of the tasks and the order of the light conditions were randomized to minimize a learning effect. Rest periods were given between tasks and conditions to minimize any learning effect that might occur and to avoid fatigue. Immediately after completing all 'off' medication testing procedures, the subjects took their anti-parkinsonian medications and were asked to wait approximately 45 minutes for 'on' medication testing. The same testing procedures were followed as were done during the 'off' state testing. At the end of the testing, subjects were asked to complete a questionnaire regarding their views of the use of red and green light beams.

Statistical analysis

Outcome measures were gait speed, cadence, and stride length while walking on the electronic walkway; time and number of freezing episode while walking 50 feet; time, number of steps and number of freezing episodes while turning 360 degrees; and responses to the questionnaire.

All analyses were done using SPSS version 17.0. Demographic and PD data were descriptively summarized. Due to our interest in comparing the effect of the two colors, two planned t-tests were performed to compare two comparisons: 1) red versus green, and 2) green versus no light. Responses from the questionnaire were summarized to describe the perspectives of the sample regarding the light beams.

Results

Displayed in Table 1 are the characteristics of the subjects. Comparisons of gait characteristics of the three light conditions are shown in Table 2. One subject did not perform the walk on the electronic walkway or the 50-foot walk due to general tiredness from performing the turning test while 'off' medication. Therefore, data from those activities were available for only 6 subjects. No significant differences were found in self-selected gait speed and cadence when walking with a cane with no, red or green light during 'off' medication. However, stride length was longer when walking with the green light than when walking with no light cue ($p = .005$).

For the 50-foot walk test during ‘off’ medication, the numbers of freezing episodes were fewer when using the green light beam than when using the red light beam ($p = .042$) or no light beam ($p = .025$). Time to perform the 50-foot walk was decreased when using the green light beam compared to the red and no light beam, however, these differences were not significant.

For turning 360 degrees during ‘off’ medication, time to complete a turn was shorter when using the green color cue compared to the red color cue ($p = .02$). The number of steps to turn with the green light beam was significantly fewer than when turning with the red light beam ($p = .043$) and when turning without a light ($p < .0005$). The number of freezing episodes significantly decreased when turning with the green light compared to the red light ($p = .03$) or no light ($p = .026$). When the subjects were ‘on’ medication, gait speed when walking with the green light beam was faster than with the red light beam ($p = .001$). No significant differences in cadence were found among the three light conditions. Stride length was longer when walking with a green light beam compared to walking without a light ($p = .004$) and when compared to walking with a red light beam ($p < .0005$).

During ‘on’ medication, time to complete the 50-foot course and the number of freezing episodes did not show any significant difference among the three light conditions. For the turning test, no difference on time to turn was found among the three light conditions. The number of steps to complete a turn was fewer when turning with the green light beam than without a light ($p = .043$).

In Table 3 are the responses from the subjects regarding the use of the light cue conditions. Most responders (6 out of 7) reported that the green light cue helped their freezing better than the red light beam. One subject reported that both colors helped prevent freezing equally. The majority of the responders reported that the light helped the most when they did the 50-foot walk and when they turned. Other responses were; 1) Red color made a person want to stop, 2) Red color helped but not as much as green, 3) Green is better to see and follow, 4) Green color made a person want to walk without freezing.

Discussion

Effect of Light Color on Gait

In this study, a green light cue improved stride length during both ‘off’ and ‘on’ medication states. Gait improvement was greater during ‘on’ medication than ‘off’ medication. These effects suggest that medications and visual cues may have an additive effect on gait performance in persons with PD. Our results are in consistent with a previous study that visual cues improved stride length. Jiang and Norman tested 14 subjects with PD and reported that the subjects started walking with longer steps, greater push-off force and higher velocity when presented with transverse line visual cues compared to the baseline condition without cues [9].

Similar findings have been reported in other studies [8; 13; 19]. Prokop et al. reported that using a dynamic visual cue (optic flow giving the illusion of walking in a tunnel) modulated walking velocity related to stride length, without influencing cadence or stride frequency in

normal subjects [19]. Our light beam was used as a dynamic visual cue in which the light cue was being carried and moved along with the subjects as they walked. Azulay et al. reported that the perceived motion of stripes on the floor induced by the patient's walking, was essential to improving gait parameters [13]. In another study, special eye glasses which had light emitting diodes that produce optical stimulation on peripheral vision were used in persons with PD. The glasses were reported to influence various gait parameters depending on the severity of PD and whether subjects were told to increase stride length (attentional strategy) [8].

Although there were significant effects of visual cue color on gait patterns and turns while 'on' medications, there was no effect on performance during the 50-foot walk. This may be due to the fact that our test course consisted of a 25-foot walkway which required a 180° turn at the end before returning to the starting point. Thus, it is impossible to separate the effect of the visual cue color on FOG during the straight walk from the effect on the turn.

Effect of Light Color on 360° Turn

During 'off' medication testing, the green light reduced time, number of steps, and number of freezing episodes more than the red light beam and reduced the number of steps and number of freezing episodes compared with no light cue. However, this effect was not found during 'on' medication. The resistance of freezing to the influence of visual cues while 'on' medication has been reported earlier. Kompoliti et al. demonstrated that assistive devices with visual cues were not consistently beneficial in overcoming freezing while 'on' medication in patients with PD [7]. This could be due to the unpredictable, variable and untreatable nature of freezing in persons with advanced PD and its complex relationship with anti-parkinsonian medications.

Transverse line visual cues have enabled people with PD to begin walking with longer steps, greater push-off force and higher velocity [9]. Visual cue lines that were oriented transversely to the direction of walking were reported to enhance activation in the right lateral premotor cortex (PMC) to a significantly greater degree than in age-matched control subjects without PD. It was postulated that the PMC compensates for the impaired supplemental motor area in persons with PD [20].

Glickstein and Stein suggested that the properties of the visual stimuli that are effective in helping the patients control their movements are similar to those of the visual signals relayed to the cerebellum. An intact cerebellar pathway may allow patients with PD to bypass their poorly functioning basal ganglia and enable them to use vision to guide their movements [21]. Marsden and Obeso also proposed that the cerebellum might be the alternative pathway used in PD to compensate for the basal ganglia deficit [22]. The visual cues generate an optical flow that may activate a cerebellar visual-motor pathway [13]. The visual cues draw the attention of the patients, thereby invoking alternative, more conscious motor control pathways in the regulation of gait. Visual cues help to fill in for the motor set deficiency by providing visual data on appropriate stride lengths [23].

Our results showed that during 'off' medication the green light beam reduced FOG more than the red light. It might be due to a general perception that a green light means "go" and a

red light means “don’t go” or “stop” as indicated by traffic signals. Another reason could be that the green color beam appeared brighter (approximate wavelength of 532 nm) than the red light (approximate wavelength of 650 nm) in the testing environment. Responses from the questionnaire regarding the subjects’ perception of the effectiveness of the two light colors demonstrated that most subjects believed that the green light helped the most during turning and the 50-foot walk.

In summary, the mechanisms of visual cueing on movement in PD could have several different explanations. Visual cues probably facilitate a visual-motor pathway, thus leading to an improvement of movement in PD. The provision of cues might help in recruiting more cortical areas to generate movements. However, the precise mechanisms behind the improvements in stride length and FOG that arise with the use of visual cues are not well understood. Our results only demonstrated that the green color reduced FOG better than the red color light. No possible mechanism was found in the literature to explain this finding. Clearly, further studies are required to assess how different colored light cues affect mobility and FOG in persons with PD.

Study Limitations

There are several limitations of the study. First, generalizability of the study may be limited by the fact that the subjects were not tested for cognitive impairment. FOG is reported to be associated with cognition disturbance [24; 25]. Second, our sample size was small, which also contributes to the limitation in generalizability of the results. Third, due to measurement difficulties and the variable nature of FOG, we were not able to time each freezing episode in this study. Thus, our timed test included both ambulation time and halted time from freezing episodes. Therefore, we were not able to determine whether the green and red color cues shortened the periods of freezing. Fourth, FOG was not a consistent and predictable phenomenon. We recruited only persons with PD who experienced FOG, especially during walking and turning. However, not all subjects demonstrated FOG when performing every walking and turning task during the experiment. The multiple t-tests may have increased the likelihood of a type 1 error.

Conclusion

The results provide initial clinical evidence regarding the effectiveness of a green light cue on a cane in alleviating FOG problems in persons with PD. If confirmed in larger studies, the results might benefit gait rehabilitation in persons with PD by influencing the choice of a light cue color.

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Figure I.
Canes with red and green light beams

TABLE 1

Subject Characteristics (N = 7; 6 males, 1 female)

Subject Characteristics	Mean (SD)
Age	71.29 (7.57)
Height (cm)	175.99 (11.24)
Weight (kg)	76.61 (11.24)
BMI (kg/m ²)	24.76 (3.41)
Years of PD	9.21 (3.76)
H&Y	3.29 (0.49)
UPDRS III (Off)	31.86 (4.30)
UPDRS III (On)	22.14 (4.10)
FOG_Q	12.86 (2.85)

Table 2

Effect of Red and Green Light Beams on Gait Characteristics, Turning and Long Walk.

Measures	OFF Medications			ON Medications		
	No Light Mean (SD)	Red Light Mean (SD)	Green Light Mean (SD)	No light Mean (SD)	Red Light Mean (SD)	Green Light Mean (SD)
Gait Speed (cm/s) ⁺	64.77 (11.58)	63.92 (23.29)	68.22 (26.70)	88.20 (19.51)	85.29 (20.14) *	94.91 (22.80) *
Cadence (step/min) ⁺	95.70 (6.12)	84.43 (17.12)	84.02 (26.44)	107.01 (10.62)	104.76 (13.34)	107.64 (9.62)
Stride Length (cm) ⁺	81.91 (12.05) #	89.18 (15.95)	97.50 (16.40) #	97.00 (26.55) #	99.65 (23.97) *	109.63 (22.86) #,*
50-foot walk ⁺						
- Time (s)	23.18 (5.32)	22.52 (2.16)	20.37 (2.95)	18.29 (3.2)	17.56 (2.10)	16.86 (2.21)
- No. Freezing Episodes	0.67 (0.52) #	0.83 (0.75) *	0.00 (0.00) #,*	0.29 (0.49)	0.14 (0.38)	0.00 (0.00)
Turning						
- Time (s)	28.34 (24.35)	19.85 (14.55) *	16.19 (11.61) *	14.25 (12.40)	11.61 (6.72)	9.63 (6.25)
- No. of Step	23.43 (4.32) #	18.00 (4.87) *	15.57 (6.08) #,*	16.57 (5.83) #	14.57 (5.53)	12.14 (4.10) #
- No. Freezing Episodes	2.14 (1.35) #	1.43 (0.98) *	0.29 (0.49) #,*	1.00 (1.00)	0.57 (0.79)	0.57 (0.79)

⁺ Data from 6 subjects;

No Light Cue vs. Green Light Cue, p value <.05;

* Red Light vs. Green Light, p value <.05;

Table 3

Responses to Questionnaire

Questions	No. of Responses (N=7)
Which light beam helped your freezing the most?	
- Green light	6
- Red light	0
- Neither helped	0
- Both help equally	1
When did it help you the most?	
- Short walk	0
- Long walk	3
- Turn	4
- None helped	0
What did you like about:	
- Red light	Helped, but not as much as green; Red made me want to stop more.
- Green light	Helped [by] increasing stability while turning; Helped me walk better; Higher visibility; Better to see and follow; It is easier to turn with green; Made me want to walk without freezing.