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The Effect of Visual Cues on the Number and Duration of Freezing Episodes in Parkinson's Patients

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Abstract—**Freezing of gait is a phenomenon common in Parkinson's patients and significantly affects quality of life. Sensory cues have been known to improve walking performance and reduce freezing of gait. Visual cues are reported to be particularly effective for this purpose. So far, sensory cues have generally been provided continuously, even when currently not needed. However, a recent approach suggests the provision of cues just in the case that freezing actually occurs. The arguments in favor of this "on-demand" cueing are reduced intrusiveness and reduced habituation to cues. Here, we analyzed the effect of visual cues on the number and duration of freezing episodes when activated either just "on-demand" or continuously and compare it to the baseline condition where no cue is provided. For this purpose, 7 Parkinson's patients regularly suffering from freezing of gait repeatedly walked a pre-defined course and their reaction to parallel laser lines projected in front of them on the floor was analyzed. The results show that, in comparison to the baseline condition, the mean duration of freezing was reduced by 51% in continuous cueing and by 69% in "on-demand" cueing. Concerning the number of freezing episodes, 43% fewer episodes were observed for continuous cueing and 9% less episodes for "on-demand" cueing.**

I. Introduction

Parkinson's disease (PD) is a neurodegenerative disease of the central nervous system severely impairing a subject's motor function. The reasons that lead to this disease are not yet fully understood. So far it is known that in Parkinson's patients, neurons in the basal ganglia, which are responsible for dopamine production, start dying. Dopamine is an important neurotransmitter for the transmission of neural signals in the basal ganglia. The consequence of the death of those neurons is an impaired motor function. The possible occurring symptoms are various. Particularly impairing symptoms are gait disturbances and freezing of gait (FOG) due to an unpredictable loss of control over movement. Characteristic for FOG are leg trembling in place, moving forward with very small steps, or total akinesia. Those symptoms seriously affect the quality of life of patients due to an increased risk of falls and a withdrawal from public life.

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It has been reported that sensory cues of different modalities (lines on the floor, rhythmic music, vibratory cues, etc.) lead to improved walking and reduce the number of freezing episodes. Several studies have focused on the effect of sensory cues on stride length and walking speed and indicate improvements of both when applying visual cues on the floor [1-5], rhythmic auditory cues [6-10]. or rhythmic vibratory cues [11]. Other studies investigated the effect of cueing on the number of FOG episodes during normal walking and report a reduced number of episodes for visual cues on the floor [12-13] and rhythmic auditory cues [14]. Further experiments investigated the effect of cueing on different parameters at gait initiation. Burleigh-Jacobs et al. [15] reported that a one-time somatosensory cue was as effective as levodopa in improving the timing and movement outcome of gait initiation. Jiang et al. [16] concluded that visual cues in the form of lines on the floor did not improve the timing/speed of gait initiation but significantly improved movement amplitudes at gait onset. In contrast, rhythmic auditory cues had no impact on gait initiation. Dibble et al. [17] demonstrated a negative effect of rhythmic somatosensory and auditory cues on sacral displacement and step length at gait initiation, probably due to unpredictable cueing intervals which hampered synchronization and therefore negatively affected gait initiation. Concerning the effect of cueing on turns, it was shown that rhythmic cues helped to speed up turns [9, 18] and significantly reduce gait-timing variability [19].

In summary, existing studies have so far generally focused on the analysis of the effect of sensory cues on different walking parameters during normal walking, at gait initiation and at turns. Most experiments were carried out with PD patients showing gait disturbances but no FOG. The only parameter concerning FOG investigated so far is the number of freezing episodes in different cueing conditions. In existing studies, usually "continuous cueing" is applied, meaning that the particular cue is presented without considering if the patient currently suffers from walking impairments or not. Problems that can occur with continuous cueing are the intrusiveness of the cue and a possible habituation effect that reduces efficiency. Therefore, an idea is to provide just cues on-demand when FOG already occurred [20, 22]. The purpose of this study is to verify the practicability of this new idea experimentally. To do so, the effect of a visual cue in form of parallel lines projected on the floor, provided either (1) continuously or (2) "on-demand" for a period of 10s, on the duration and the number of FOG episodes is investigated.

II. METHODS

A. Patients

To test the effect of visual cues on freezing episodes, the gait of 7 Parkinson's patients (see table 1) regularly suffering from FOG was observed and analyzed over a whole medication cycle. The average age of the subjects was 75 years and their average FOG score [21] was 13.4. Ethical approval for the performed study was received from the CEIC-E (Comité Ético de Investigación Clínica de Euskadi).

TABLE I. SUMMARY OF PATIENT CHARACTERISTICS

Patient ID	*Gender*	*Age*	*Walking Aid*	*Falls/ month*	*Type of FOG*	*FOG Score*
1	M	80	-	1-2	ON/OFF	12
2	M	74	-	0.5	OFF	13
3	M	83	-	-	OFF	14
4	F	69	Cane	-	ON	11
5	M	75	Wheelchair /Walker	-	ON/OFF	19
6	M	72	Cane	1	ON/OFF	12
7	M	74	-	1-2	OFF	13

B. Experimental Setup

The objective of the experiment was to quantify how visual cues affect the number and duration of FOG episodes. Accordingly, participants were asked to walk a predefined course in an observation laboratory with the appearance of a normal apartment (see figure 1). The course consisted of the following tasks:

1. Standing up from a chair and getting a glass of water from the kitchen
2. Going with the glass to the bathroom and leaving the glass on the washbasin
3. Walking to the bedroom and picking up a clothes hanger from the cupboard
4. Carrying a clothes hanger to the washing room and leaving it there
5. Going back to the chair
6. Performing tasks 1-5 in reverse order starting with task 5

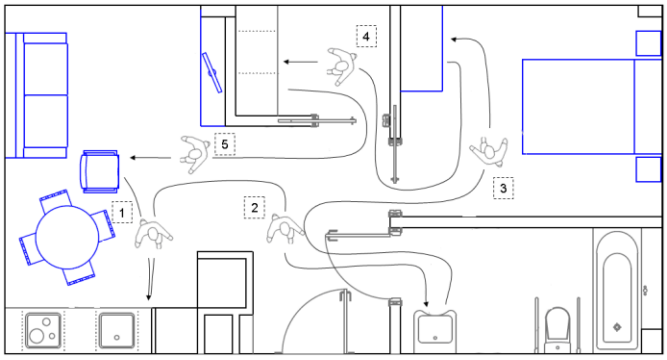

Figure 1. Course and tasks performed by the participants

For later analysis, patients were videotaped while performing these tasks. To provide the visual cue, a laser device was attached to their body. The device consisted of a small and lightweight support frame attached to the chest of the patient on which green lasers were mounted. Via specific lenses, two parallel lines were projected on the floor (30 cm in front of participant orthogonal to walking direction; 1.5m length; 40cm interline distance).

Figure 2. Lines projected in front of patient and laser device attached to chest of patient.

The lasers were controlled via a computer and either turned on continuously or just for 10s in case that FOG actually occurred during the course. To allow the triggering of the cue, patients wore a backpack with a small and lightweight laptop computer. The laptop was remote controlled by another computer via WIFI. The whole experiment was divided into cycles. In one cycle, the patient had to walk through the course 3 times under different cueing conditions: (1) baseline without cue, (2) visual cue on for 10s whenever freezing occurred (3) visual cue on continuously. The succession of the conditions was changed in every cycle. A freezing episode was defined as *"stop and/or hesitation until the next step was accomplished independently of the number of hesitations in place"* [13]. For the on-demand-triggering, an assistant experienced in the recognition of FOG episodes observed the participants performing the course and triggered a cue whenever a FOG episode occurred.

To investigate the effect of visual cues on FOG episodes, the gait of 7 patients regularly showing FOG episodes was monitored. Depending on the overall physical condition of the patients, they performed 3 to 7 cycles with breaks of 30 to 45 minutes between the cycles.

C. Data Analysis

In order to evaluate the effect that the sensory cues had on FOG, the mean duration and number of the freezing episodes under the different conditions was determined. For this purpose, the video data, which were synchronized with the cueing events, were analyzed and the number of episodes and the duration of each episode were logged with a resolution in the range of 1s. From these episodes, the mean freezing duration and the number of freezing episodes for

each patient were computed by averaging over all recorded cycles of a particular cueing condition. Additionally, the mean and standard deviation of the freezing duration and number of freezing episodes of all patients were calculated for each condition based on the mean values of each particular subject.

III. RESULTS

In table 2, the average duration and number (*mean*) and their standard deviation (*std*) of the freezing episodes of the different patients in the different cueing conditions is given. In the last line of the table, these values are averages over all patients. Two of the patients (P1, P2) did not show any freezing during the experiment and therefore had to be excluded from the further analysis. One patient (P3) showed severe freezing manifested as continuous severe shuffling with very small steps or complete immobility over the whole walking course. Interestingly, his gait could be significantly improved by providing the continuous visual cue. However, as the subject was not able to perform the baseline condition and fell back into freezing as soon as the visual cue disappeared, his data were excluded from further analysis.

TABLE II. MEAN DURATION AND NUMBER OF FREEZING EPISODES OF DIFFERENT PATIENTS IN DIFFERENT CUEING CONDITIONS

Average Duration of Freezing Episodes						
Patient	**Baseline**		**Visual 10s**		**Visual Continuous**	
	Mean [s]	**Std [s]**	**Mean [s]**	**Std [s]**	**Mean [s]**	**Std [s]**
P1	-	-	-	-	-	-
P2	-	-	-	-	-	-
P3	-	-	-	-	-	-
P4	3,7	2,3	1,3	0,6	x	x
P5	18,1	10,1	6,7	6,3	5,1	5,7
P6	3,6	1,1	2,0	0,0	3,0	0,0
P7	13,6	14,1	2,0	0,0	4,9	1,9
Patient Average	**8,8**	**7,4**	**2,7**	**2,7**	**4,3**	**1,2**

Mean: Average duration in seconds of freezing episodes in a certain condition
Std: Standard deviation in seconds of freezing episodes in a certain condition
x: no freezing occured during continuous cueing

Average Number of Freezing Episodes						
Patient	**Baseline**		**Visual 10s**		**Visual Continuous**	
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**
P1	-	-	-	-	-	-
P2	-	-	-	-	-	-
P3	-	-	-	-	-	-
P4	2,7	1,6	0,8	1,0	0,0	0,0
P5	2,3	1,5	4,3	1,5	3,3	1,5
P6	1,7	0,35	1,5	0,0	0,5	0,7
P7	2,3	3,1	1,6	2,3	1,5	1,8
Patient Average	**2,3**	**0,4**	**2,1**	**1,6**	**1,3**	**1,5**

Mean: Average number of freezing episodes in a certain condition
Std: Standard deviation of freezing episodes in a certain condition

In figure 3, the mean duration and mean number of the freezing episode averaged over all patients in the baseline condition and the two cueing conditions is illustrated graphically.

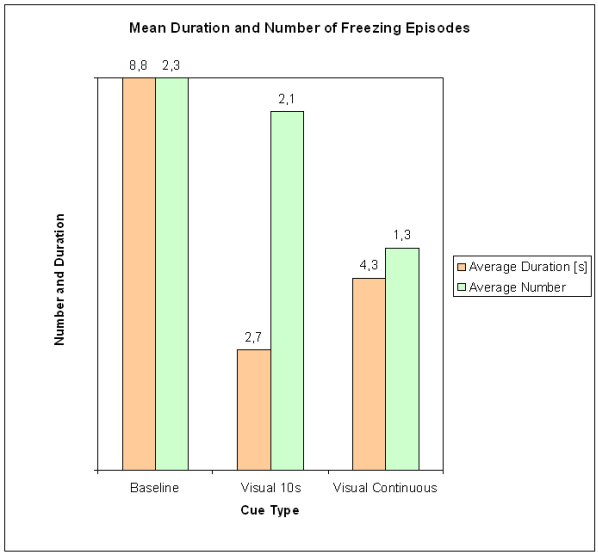

Figure 3. Mean duration and number of freezing episodes in different cueing conditions averaged over all patients

IV. DISCUSSION

Concerning the duration of freezing, table 2 and figure 3 clearly show that both continuous and on-demand cueing lead to a significant reduction of the duration of freezing episodes (2.7s for on-demand cueing and 4.3s for continuous cueing) in comparison to the uncued baseline condition (8.8s). This trend was consistent over all tested patients. This indicates that on-demand cueing is more efficient for reducing the duration of FOG episodes than continuous cueing. A possible explanation for this effect is that the higher saliency of "on-demand" cueing better directs the patients' attention back to the walking task.

Concerning the number of episodes per course, continuous cueing reduced the average number to 1.3 in comparison to the baseline condition (2.3). Interestingly, the on-demand visual cue being active only for 10s after the start of FOG episodes also slightly reduced the number of episodes (2.1). This is somewhat surprising because in the "on-demand" condition cues were only triggered after FOG episode were observed. A possible explanation for this effect is that the cue was active always for 10s and that the probability for the occurrence of another freezing episode during this period was therefore lower. The described effect could be observed in three out of four patients. In patient P5, both visual cues led to an increase of the number of FOG episodes.

V. CONCLUSION

The article analyzed the effect of visual cues in form of parallel laser lines projected on the floor on the number and duration of freezing episodes when activated either just "on-demand" or continuously and compared it to the baseline condition where no cue is provided. The results show that on-demand cueing seems to be more effective to reduce the duration of freezing episodes than continuous cueing, probably because of its higher saliency. On the other hand, on-demand cueing had little effect on the number of freezing

episodes while continuous cueing proved to avoid a certain percentage of freezing episodes. Reducing the number of freezing episodes is particularly important to reduce the risk of falling for the patients, which is the highest during the first few seconds of a freezing episode.

However, due to the small number of patients tested, the results presented here should be understood as a first indication for the relative usefulness of continuous and "on-demand" cueing.

The next steps that have to be taken are to verify the findings just described with a bigger number of patients and to test if the effects are resistant to habituation due to use of cuing over longer time periods. Given that these further studies lead to promising results and that patient resonance is positive, a further step would be to develop practical and non-obtrusive assistive devices providing such visual cues for gait support in Parkinson's patients.

REFERENCES

[1] Bagley S, Kelly B, Tunnicliffe N, Turnbull GI, Walker JM. The effect of visual cues on the gait of independently mobile parkinson's disease patients. Physiotherapy. 1991;77:415–420.

[2] Morris ME, Iansek R, Matyas TA, Summers JJ. Stride length regulation in parkinson's disease. normalization strategies and underlying mechanisms. Brain. 1996;119(Pt2):551–568.

[3] Azulay JP, Van Den Brand C, Mestre D, Blin O, Sangla I., Pouget J, et al. Automatic motion analysis of gait in patients with parkinson disease: effects of levodopa and visual stimulations. Rev Neurol (Paris). 1996;152(2):128–134.

[4] Azulay JP, Mesure S, Amblard B, Blin O, Sangla I, Pouget J. Visual control of locomotion in parkinson's disease. Brain. 1999;122(Pt1):111–120.

[5] Lewis GN, Byblow WD, Walt SE. Stride length regulation in parkinson's disease: the use of extrinsic, visual cues. Brain. 2000;123 (Pt10):2077–2090.

[6] Enzensberger W, Fischer PA. Metronome in parkinson's disease. Lancet, 1996;347.

[7] McIntosh GC, Brown SH, Rice RR, Thaut MH. Rhythmic auditory-motor facilitation of gait patterns in patients with parkinson's disease. J. Neurol. Neurosurg. Psychiatry. 1997;62:22–26.

[8] Ito N, Hayshi A, Lin W, Ohkoshi N, Watanabe M, Shoji S. Music therapy in Parkinson's disease: Improvement of Parkinsonian gait and depression with rhythmic auditory stimulation. Integrated human brain science: theory, method, application (music). Elsevier. 2000;435–443.

[9] Arias P, Cudeiro J. Effect of Rhythmic Auditory Stimulation on Gait in Parkinsonian Patients with and without Freezing of Gait. PLoS ONE. 2010;5(3):e9675. doi:10.1371/journal.pone.0009675.

[10] Bryant MS. An evaluation of self-administration of auditory cueing to improve gait in people with Parkinson's disease. Disabil Rehabil Assist Technol. 2009;4(5): 357–363.doi:10.1080/17483100903038576.

[11] Van Wegen E, De Goede C, Lim I, Rietberg M, Nieuwboer A, Willems A, et al.. The effect of rhythmic somatosensory cueing on gait in patients with parkinson's disease. Journal of the Neurological Sciences. 2006;248:210–214.

[12] Dietz MA, Goetz CG, Stebbins GT. Evaluation of a modified inverted walking stick as a treatment for parkinsonian freezing episodes. Mov Disord. 1990;5(3):243–247.

[13] Kompoliti K, Goetz CG, Leurgans S, Morrissey M, Siegel IM, "On" freezing in Parkinson's disease: Resistance to visual cue walking devices, Movement Disorders, 2001;15(2):309–312.

[14] Cubo E, Leurgans S, Goetz CG. Short-term and practice effects of metronome pacing in Parkinson's disease patients with gait freezing while in the 'on' state: randomized single blind evaluation. Parkinsonism and Related Disorders, 2004;10(8):507-510.

[15] Burleigh-Jacobs A, Horak FB, Nutt JG, Obeso JA. Step initiation in parkinson's disease: influence of levodopa and external sensory triggers. Mov Disord. 1997;12(2):206–215.

[16] Dibble LE, Nicholson DE, Shultz B, MacWilliams BA, Marcus RL, Moncur C. Sensory cueing effects on maximal speed gait initiation in persons with parkinson's disease and healthy elders. Gait Posture, 2004;19(3):215–225.

[17] Jiang Y, Norman KE. Effects of visual and auditory cues on gait initiation in people with parkinson's disease. Clin Rehabil, 2006;20(1):36–45.

[18] Nieuwboer A, Baker K, Willems AM, Jones D, Spildooren J, Lim I, et al. The short-term effects of different cueing modalities on turn speed in people with parkinson's disease. Neurorehabil Neural Repair. 2009;23(8):831–836.

[19] Willems AM, Nieuwboer A, Chavret F, Desloovere K, Dom R, Rochester L, et al. Turning in parkinson's disease patients and controls: The effect of auditory cues. Movement Disorders, 2007;21:1871–1878.

[20] Zabaleta H, Keller T, Fimbel E. Method to detect physical blocking episodes on an individual activity, Patent application WO/2009/083032. 2007.

[21] Giladi N, Shabtai H, Simon ES, Biran S, Tal J, Korczyn AD. Construction of freezing of gait questionnaire for patients with Parkinsonism. Parkinsonism and Related Disorders. 2000; 6:165–170.

[22] Velik R, Hoffmann U, Zabaleta, H, Martí-Massó JF. Effect of sensory cues applied at the onset of freezing episodes in Parkinson's disease patients, International Journal of Medical and Biological Sciences, 6:57–62, 2012.