The Possible Price of Auditory Cueing: Influence on Obstacle Avoidance in Parkinson’s Disease

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ABSTRACT

Background: Under carefully controlled conditions, rhythmic auditory cueing can improve gait in patients with Parkinson’s disease (PD). In complex environments, attention paid to cueing might adversely affect gait, for example when a simultaneous task—such as avoiding obstacles—has to be executed. We primarily examined whether concurrent auditory cueing interferes with an obstacle avoidance task in patients with PD. The secondary aim was to study differences between patients with and without freezing of gait.

Methods: Nineteen patients with PD (8 with freezing) were examined on a treadmill in 4 conditions: normal walking; walking with auditory cueing; walking with an obstacle avoidance task; and walking with auditory cueing and obstacle avoidance. Outcome measures included kinematic gait parameters and obstacle crossing parameters.

Results: Auditory cueing improved gait in PD, without negative effects on concurrent obstacle avoidance. Additionally, freezers avoided obstacles less efficiently than non-freezers.

Conclusions: PD patients are able to successfully execute an obstacle avoidance task, when auditory cueing is administered simultaneously. The different obstacle avoidance behavior in freezers may contribute to their higher fall risk. © 2012 Movement Disorder Society

Key Words: auditory cueing; dual task; freezing of gait; obstacle avoidance; Parkinson’s disease

Gait in Parkinson’s disease (PD) is characterized by slow gait speed, decreased stride length, and increased cadence.1–3 Additionally, 30% to 60% have freezing of gait (FOG).4 These gait deficits contribute to the high frequency of falls in PD.5,6

Training with external cues, such as rhythmic auditory stimulation, can rehabilitate gait in PD by increasing stride length7,8 and diminishing FOG.8,9 However, the effects of auditory cueing may differ for patients with or without FOG: with auditory cueing set at a higher cadence than preferred, “non-freezers” increase their stride length, while “freezers” decrease their stride length.10

Although auditory cueing improves gait in PD under carefully controlled conditions, it could also aggravate gait by acting as a “dual task” that draws attention away from other resources. Indeed, gait in PD deteriorates when another task has to be performed simultaneously.11–13 Freezers are more adversely affected by dual tasking.14,15 Hence, auditory cueing might complicate gait when a complex secondary task (e.g., obstacle avoidance) must be executed simultaneously. For example, FOG episodes can be provoked when freezers must switch from 1 motor program to another; e.g., from stable gait to an obstacle avoidance task.16

Here, we primarily examined the influence of concurrent auditory cueing on obstacle avoidance in PD patients. As a secondary question, we separately analyzed freezers and non-freezers.

Patients and Methods

Subjects

We included 19 PD patients.17 The study was approved by the local ethics committee. All subjects gave prior written informed consent according to the Declaration of Helsinki. Patients were examined in an off state, >12 hours after withdrawal of dopaminergic medication.
According to the new FOG Questionnaire,\textsuperscript{18,19} eight patients had FOG. These freezers were matched for age, gender, disease severity, and disease duration with the 11 non-freezers (Table 1). Exclusion criteria included inability to walk independently on a treadmill, cognitive impairment, other causes of gait disturbances, major psychiatric disorders, or severe comorbidity.

**Study Design**

Subjects were examined during 4 conditions: normal walking at preferred cadence (BASELINE condition, 1 minute of recording); walking with auditory cueing (CUEING condition, 1 minute of recording); walking with an obstacle avoidance task (OBSTACLE condition, 10 trials); and walking with both auditory cueing and the obstacle avoidance task (OBSTACLE WITH CUEING, 10 trials). All conditions were performed on a treadmill set at 2 km/h. Spatiotemporal data were collected for each condition, using a 6-camera motion analysis system (Vicon; Oxford Metrics, Oxford, UK).

During the cued conditions, the metronome was set at the preferred cadence of each patient (determined during baseline walking) minus 10%\textsuperscript{20,21} Subjects had to synchronize their heel strikes with the metronome sound.

Obstacle avoidance was performed as described previously.\textsuperscript{16,22} We used an obstacle with a length of 400 mm, width of 300 mm, and height of 15 mm. The obstacle was suddenly dropped on the treadmill and had to be crossed with the patients’ most affected leg over the widest side.

**Outcome Measures**

We measured gait parameters (stride length, stride time, and cadence) to examine the effect of auditory cueing. Gait parameters during the obstacle conditions were measured from the first step after obstacle crossing. The outcomes for obstacle avoidance were foot clearance (maximal vertical distance between toe and obstacle), success rate, and length and velocity of the obstacle crossing step, measured from last toe-off before obstacle crossing until first heel strike of the same foot after obstacle crossing.\textsuperscript{22,23} Success rate was calculated as the percentage of trials without errors; an error was scored when the subject stepped on or next to the obstacle with the crossing foot. We also examined metronome synchronization as the delay in time between metronome sound and heel strike. Statistical analyses are described in the Supporting Information.

**Results**

**Auditory Cueing**

Compared to baseline, auditory cueing improved stride length, stride time, and cadence (repeated measures analysis of variance [ANOVA], significant main effect of condition, $P < .001$; Supporting Table 1). These effects were equally present in freezers and non-freezers (repeated measures ANOVA, no significant group*condition interaction). No FOG episodes occurred during the actual experiment. Moreover, there were no differences in baseline gait characteristics between freezers and non-freezers.

Auditory cueing also improved all gait variables during the OBSTACLE WITH CUEING condition (repeated measures ANOVA, significant main effect of condition, $P < .001$; Supporting Table 1). This effect did not differ between both patient groups (repeated measures ANOVA, no significant group*condition interaction).

**Effect of Auditory Cueing on Obstacle Avoidance Task**

For the entire patient group, mean success rate was 97.9 ± 1.2% during the OBSTACLE condition, and 97.4% ± 1.5% during the OBSTACLE WITH CUEING condition. Obstacle avoidance performance did not change when auditory cueing was administered simultaneously (repeated measures ANOVA, no significant effect of condition for all variables; Supporting Fig. 1). Moreover, this was the same in freezers and non-freezers.

### Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>PD patients (n = 19)</th>
<th>Freezers (n = 8)</th>
<th>Non-freezers (n = 11)</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>57.0 ± 8.4</td>
<td>53.8 ± 7.6</td>
<td>59.3 ± 8.5</td>
<td>.161</td>
</tr>
<tr>
<td>Women (%)</td>
<td>47.4</td>
<td>37.5</td>
<td>55</td>
<td>.490</td>
</tr>
<tr>
<td>H&amp;Y</td>
<td>2.2 ± 0.3</td>
<td>2.2 ± 0.3</td>
<td>2.1 ± 0.2</td>
<td>.139</td>
</tr>
<tr>
<td>UPDRS (part III)</td>
<td>17.4 ± 6.6</td>
<td>19.6 ± 7.2</td>
<td>15.7 ± 6.0</td>
<td>.213</td>
</tr>
<tr>
<td>Disease duration (y)</td>
<td>6.4 ± 4.3</td>
<td>7.9 ± 5.5</td>
<td>5.3 ± 3.1</td>
<td>.204</td>
</tr>
<tr>
<td>MMSE (maximum 30)</td>
<td>28.5 ± 2.0</td>
<td>29.0 ± 0.9</td>
<td>28.2 ± 2.5</td>
<td>.396</td>
</tr>
<tr>
<td>FAB (maximum 18)</td>
<td>16.5 ± 1.7</td>
<td>15.5 ± 2.1</td>
<td>17.3 ± 0.8</td>
<td>.180</td>
</tr>
<tr>
<td>NFOG-Q score (maximum 24)</td>
<td>–</td>
<td>12.0 ± 5.3</td>
<td>0.0 ± 0.0</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Values are means ± SD except where indicated.

*Differences between freezers and non-freezers, assessed with Student $t$ test ($P < .01$). $n$, number of subjects; NS, not significant; MMSE, Mini Mental State Exam; FAB, Frontal Assessment Battery; UPDRS, Unified Parkinson’s Disease Rating Scale; H&Y, Hoehn & Yahr; NFOG-Q, New Freezing of Gait Questionnaire.
non-freezers separately (repeated measures ANOVA, no significant interaction effect of group*condition). This indicates that both freezers and non-freezers were capable of performing obstacle avoidance and auditory cueing simultaneously. Patients adequately reacted to auditory cueing during obstacle avoidance, as shown by comparable metronome synchronization in the CUEING and OBSTACLE WITH CUEING condition (data not shown).

**Effect of Auditory Cueing in Freezers and Non-Freezers**

Freezers performed worse on obstacle avoidance, as reflected by a smaller crossing step length (repeated measures ANOVA, significant main effect of group, \( P = .004 \)) and trends toward a lower crossing step velocity (\( P = .024 \)) and a lower foot clearance (\( P = .045 \)). Success rate did not differ between freezers and non-freezers.

Figure 1 illustrates obstacle avoidance task performance for non-freezers and freezers during the OBSTACLE condition. Crossing step length in freezers was 23.7% lower compared to non-freezers (Mann Whitney \( U \) test, \( P = .005 \)). Additionally, foot clearance (24.6%, \( P = .013 \)) and crossing step velocity (22.9%; \( P = .031 \)) tended to be smaller in freezers.

For the OBSTACLE WITH CUEING condition, crossing step length was also 29.1% lower in freezers (\( P = .001 \), and foot clearance (21.7%; \( P = .045 \)) and crossing step velocity (26.3%; \( P = .013 \)) tended to be decreased. However, success rates did not differ between freezers and non-freezers during both the OBSTACLE condition and the OBSTACLE WITH CUEING condition.

**Discussion**

We examined whether auditory cueing might interfere with obstacle avoidance in PD during treadmill walking. PD patients—both freezers and non-freezers—were able to successfully avoid obstacles when auditory cueing was administered simultaneously. As an incidental observation, we found that freezers had poorer obstacle avoidance compared to non-freezers.

**Auditory Cueing and Obstacle Avoidance**

Auditory cueing did not interfere with obstacle avoidance in PD, not even in patients with FOG. This was unexpected, because freezers are more adversely
affected by a dual task than non-freezers and gait can be worsened if freezers are forced too hard to modify their cadence. However, both freezers and non-freezers benefited from auditory cueing, without paying a price on either of the separate tasks.

In an earlier study, in which PD patients had to listen to music and simultaneously avoid obstacles during overground walking, patients decreased their obstacle crossing velocity, without differences in spatial parameters. In contrast, in our study auditory cueing did not affect spatial or temporal parameters of obstacle crossing. This could be explained by the therapeutic effects of the pacing metronome, which may have assisted patients in taking larger steps. Therefore, our data suggest that PD patients can benefit from auditory cueing even under complex, attention-demanding circumstances, and that the metronome does not act as a dual task that negatively affects gait.

Our results alleviate theoretical concerns that cueing (evidence-based treatment in PD) could have adverse effects under complex, attention-demanding circumstances. This ability to profit from cueing while maintaining successful obstacle avoidance was present even though we measured patients off medication. In normal life, medication effects during the on phase may further facilitate dual tasking. Recent studies examined dual task training by letting PD patients focus on taking larger steps during walking under dual tasks conditions. Indeed, patients could maintain walking with large steps and performed the dual task successfully. Together with our results this suggests that dual task training in PD can be beneficial.

Obstacle Avoidance in Freezers

Obstacle avoidance was less efficient in freezers compared to non-freezers (reduced step length of the obstacle crossing step). Moreover, foot clearance and obstacle crossing step velocity just failed to reach significance due to the conservative P value, but there appeared to be a relevant reduction of at least 20% compared to non-freezers. These incidental findings must be interpreted carefully, as this was not our primary goal. However, it is potentially interesting, because obstacle avoidance has not been examined previously in patients with FOG. Previous studies did examine obstacle avoidance behavior in PD during overground walking and treadmill walking. The results were inconsistent, likely due to differences in instructions or differences in patient characteristics. We previously examined treadmill gait in freezers and non-freezers and found a reduced step length in freezers. This difference in baseline gait may partly underlie the reduced obstacle crossing step in the current study.

Less efficient obstacle avoidance in freezers may have clinical implications, because this could increase the risk of tripping over obstacles and contribute to falls. Indeed, FOG is an important cause of falls in PD and this may be caused not only by freezing events, but perhaps also by stumbling. Future research should corroborate these findings, focusing in particular on the association between obstacle avoidance behavior and falls in freezers. If confirmed, it may be worthwhile to train freezers how to better avoid obstacles; eg, by taking larger steps and lifting their feet higher during obstacle crossing.

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References


