Weighting for the beat:
Using a dance cue to facilitate turning in people with Parkinson's Disease and freezing of gait

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ABSTRACT

Freezing of Gait (FOG) can severely compromise daily functioning in people with Parkinson's Disease. Inability to initiate a step from FOG is likely underpinned, at least in part, by a deficient preparatory weight-shift. Conscious attempts to weight-shift in preparation to step can improve success of initiating forward steps following FOG. However, FOG often occurs during turning, where weight-shifting is more complex and risk of falling is higher. We explored the effectiveness of a dance-based ('cha-cha') weight-shifting strategy to re-initiate stepping following FOG during turning. Results suggest that this simple movement strategy can enhance turning steps following FOG, without compromising safety.

INTRODUCTION

Freezing of Gait (FOG) — defined as "an episodic inability (lasting seconds) to generate effective stepping" (p. 424) [1] — is one of the most common symptoms of advanced Parkinson's Disease (PD) [2,3]. FOG is highly debilitating and is associated with increased falls, loss of independence and reduced quality of life [4-6]. FOG is often resistant to pharmacological and surgical interventions [7], emphasising the need to develop novel therapeutic strategies [8].

Compensatory strategies – often involving the provision of sensory information, such as auditory and/or visual cues – are emerging as a primary focus in research. These are typically employed to improve gait characteristics and *prevent* FOG occurring [9,10]. In contrast, strategies used to overcome FOG once it has occurred (so-called 'rescue' strategies) have received comparatively less attention.

To initiate a step, we must first transfer our weight onto the non-stepping leg; a process known as an anticipatory postural adjustment (APA). A successful APA consists of (1) an initial transfer of weight toward the stepping leg, immediately followed by (2) a rapid weight shift away from the stepping leg, and (3) forward propulsive movement [11]. The ability to generate the initial preparatory transfer of weight towards the non-stepping leg is often deficient in people with FOG pathology [12], potentially hindering their ability to effectively step out from a freezing episode [13]. It is therefore important to find effective 'rescue' strategies that facilitate these preparatory weight-shifting actions that are associated with successful step initiation.

Anecdotal reports indicate that people experiencing FOG employ a wide range of 'rescue' strategies [10]. One such strategy is the conscious execution of a preparatory weight-shift. We recently described how verbally instructed weight-shifting substantially improves the ability to initiate *forward* steps following a freeze [13]. These benefits are likely due to interacting psychological and mechanical changes, where conscious control of previously absent weight-shifting puts the individual in the physical position needed to unload the stepping leg.

While encouraging, the observations above are limited to forward stepping. However, FOG often occurs during turning, where weight-shifting is more complex and risk of falling is higher [14,15]. We therefore aimed to explore the efficacy of using a weight-shifting strategy to promote successful recovery following FOG during turning. We also investigated participants' perceptions of safety and effectiveness when using this strategy in daily life following a one-off training session.

METHODS
Participants. We recruited 14 people with idiopathic PD+FOG from local peer-support groups. Participants had no severe cognitive deficits (Montreal Cognitive Assessment>18), nor any cardiovascular, musculoskeletal, or neurological impairments (other than PD) that affected balance. All participants used dopamine-replacement therapy, with testing taking place in the ON state of

medication (~2 hours after medication intake). Participants self-identified as having PD+FOG, and this was confirmed during the initial assessment prior to the main experiment, using the Freezing of Gait Questionnaire (item 3). Background characteristics of the sample are reported in Table 1.

Table 1. Participant characteristics.

Participant	Gender (male/ female)	Age (years)	MoCA (0-30)	Years since diagnosis	Hoehn & Yahr (1-5)	UPDRS -III (0-56)*	FOGQ Item 3 (0-4)	Falls in last 6 months (yes/no)	TUG (s)
1	F	56	29	14	2	18	3	***	***
2	F	79	25	17	4	10	3	***	***
3	M	72	25	9	2	25	3	No	12.5
4	M	76	22	7	3	22	3	Yes	12.4
5	F	74	28	3	2	7	3	***	12.3
6	M	83	27	4	2	9	3	Yes	16.7
7	M	77	28	7	2	31	0**	No	15.6
8	F	76	30	5	2	15	2	No	13.9
9	M	77	28	11	2	12	3	No	12.0
10	F	64	26	14	2	13	3	No	9.1
11	F	67	26	15	2	8	3	No	11.9
12	F	80	26	8	2	19	2	No	14.1
13	M	72	25	13	4	17	3	Yes	14.5
14	M	74	26	13	2	6	3	Yes	9.6

* Assessed during on-state; ** Participant answered '0' because freezing only happened when *initiating* walking from certain positions, but not *during* walking per se; *** Missing datapoint; Abbreviations: FOGQ Item 3= Freezing of Gait Questionnaire – item 3 [16]; MoCA=Montreal Cognitive Assessment [17]; TUG = Timed-up-and-Go [18]; UPDRs=Unified Parkinson's Disease Rating scale, section 3 [19].

Turning and cueing assessment. We used a pre-post design to explore the effects of a weight-shifting dance cue (based on the cha-cha dance; described below) on participants' turning behaviour. First, participants were harnessed and fitted with a virtual reality (VR) headset (HTC Vive Sony Ltd.). The VR environment simulated standing in front of a narrow doorway at the top of a descending flight of stairs (supplementary material 1). For both pre- ('Baseline') and post-assessments ('Cha-Cha Cue'), participants started with their feet positioned hip-width apart, facing away from the staircase, and looking at a blank wall in a small virtual room. Participants were asked to turn 180 degrees rightward, stop, and turn back to the start point. They were then asked to turn 180 degrees leftward, stop, and then turn back to the start point before repeating this process. Participants thus faced the staircase either at the end or start of each turn. This was intended to induce mild anxiety and therefore provoke freezing in a way that broadly resembled a situation encountered in daily life [20,21]. In both Baseline and Cha-Cha Cue trials, participants were asked to continue turning for up to 8 minutes. Trials were terminated earlier if participants indicated becoming dizzy, tired, and/or in need of a break. We used video recordings for offline scoring of freezing events [22].

In the Baseline condition participants were only instructed to complete the turning task and, should a freeze occur, to attempt to continue turning in the same direction. No attentional cues were provided. Rather, participants were told to simply self-select the strategy that they think is most suitable to step out of the freeze, as they would do in daily life.

The Cha-Cha Cue condition always followed the Baseline condition.[1] Before the Cha-Cha Cue condition, participants removed the headset and took a short break (2-5 minutes). Next, participants were taught to use a 'cha-cha' weight-shift strategy, designed to prompt users to rhythmically shift their weight away from (i.e., unloading) the intended stepping limb; thereby facilitating the ability to step from FOG and safely continue the turn. Training involved participants standing in front of a full-length mirror and being asked to imagine they were experiencing FOG while attempting to turn. The mirror was used to provide participants with visual feedback on the execution of the weight-shift when practicing the 'cha-cha' movement, with the intent to facilitate recall of this strategy during the subsequent Cha-Cha Cue condition. No such visual feedback was provided during the Cha-Cha Cue condition itself. Participants placed their hands on their hips and swayed from side-to-side in time with the rhythm of a Latin style dance[2]. By gradually increasing the amplitude of the medio-lateral weight-shift, participants were encouraged to take a turning step once they felt their stepping leg was unloaded and free to move. With this movement being repeated over multiple consecutive beats, the participant would progress through a turn [23].

During the Cha-Cha Cue condition, participants performed the turning protocol in VR again. However, this time participants were encouraged to remember and evoke the cha-cha cue to continue the turn whenever FOG occurred. No external rhythmic cueing or music was played during this Cha-Cha Cue condition.

Analysis

Main analysis of freezing during Baseline and Cha-Cha Cued trials
The scoring process was a replication of that used in an equivalent forward-stepping task reported by Maslivec et al. [13]. Video recordings of the Baseline and Cha-Cha cued turning trials were evaluated to identify (1) if a freezing event occurred, (2) if a participant was able to successfully step out of the freeze *on their first attempt* or not (henceforth referred to as successful vs. unsuccessful initial stepping attempts), and (3) if the use of the cha-cha strategy was visually apparent (see Supplementary Material 3 for links to videos exemplifying this). FOG was determined to be present if an involuntary cessation of turning movements occurred, indicated by key characteristics such as trembling and festination. Scoring was carried out by three separate raters who scored each video independently, after which they met to reach consensus on scoring for all participants and trials. Due to the clearly visible changes in movement strategy between Baseline and Cha-Cha Cued trials, it was not possible to blind raters. However, in an attempt to reduce potential bias, 2 out of 3 raters had not been present during the actual measurements, such that prior knowledge of these sessions could not influence their assessment.

We used one-tailed Wilcoxon signed-rank tests to compare the stepping success (% of all stepping attempts) between (1) Baseline and Cha-Cha Cue conditions overall, and (2) between Baseline and Cha-Cha Cue conditions, but only for stepping attempts where participants were observed to use the Cha-Cha Cue.[3]

Participant experiences with using cue in daily life

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[1] Unpublished data from Maslivec et al. [13] showed that participants learning a weight-shifting strategy still regularly used this strategy in daily life 4 weeks post-testing. As such, we anticipated that counterbalancing the order of conditions with a washout period was not feasible.

[2] Latin dance is distinguished from other styles of dance by a rhythmic strutting of the hips, which is key to the effectiveness of the cue, hence the 'cha-cha' analogy.
[3] These analyses are somewhat analogous to an 'intention-to-treat' and 'per-protocol' analysis, respectively.

Participants completed a follow-up questionnaire (Supplementary Material 2) 3 months after the initial experiment. This gauged participants' self-guided use of the strategy, and their perception of usability and safety of the cha-cha cue when used in daily life.

RESULTS

Freezing results
Mean duration of the conditions was similar (Baseline: 230 seconds, range: 100-480 seconds; Cha-Cha Cue condition: 244 seconds, range: 66-400 seconds). In total, 109 freezing episodes were recorded for the Baseline condition, while 89 episodes were observed for the Cha-Cha Cue condition (two-tailed Wilcoxon signed-rank test: $W(14)=30.5$, $p=.504$). Ten participants experienced at least one freezing episode in both conditions. Two participants only froze during the Cha-Cha Cue condition, while two other participants did not show any freezing at all.

Table 2 shows the number of times that each participant was successful or unsuccessful at their initial attempt to step out of a freezing episode for each condition. We also present the success percentage. No falls occurred during the lab-based assessment. There was an overall significant increase in initial stepping success in the Cha-Cha Cue (median=48% success rate) condition compared to Baseline (median=15% success rate; $W(10)=43.0$, $p=.008$). Overt attempts to use the cha-cha cue were only observed for 39 out of the 89 (44%) attempts to step from a freeze. When we restricted analyses to these overt attempts, we also found a significantly higher percentage of initial successful steps (median=100%) compared to Baseline (median=15%; $W(7)=28.0$, $p=.009$).

Self-reported (experiences of) use of Cha-Cha Cue in daily life
Nine participants provided follow-up data. Of these, 7 reported to have used the cha-cha cue since the study, with 6 of these using it more than once a week. All 9 participants reported they felt safe using the cue and stated they would recommend the cue to another person with PD+FOG. Three stated they found the cue very useful, 5 said they found it somewhat useful and 1 said they felt it had no effect. None reported any adverse events (e.g., a fall) when using the cue.

Table 2. Number of successful stepping attempts per participant and condition. Both absolute number of steps and percentage of successful attempts are presented.

	Number of initial stepping attempts from freeze				% of successful initial stepping attempts from freeze		
	Baseline		Cha-Cha Cue *(in brackets number of attempts participants overtly used cue)*		Baseline	Cha-Cha Cue	Cha-Cha Cue *(overtly using cue)*
Participant	Successful	Unsuccessful	Successful	Unsuccessful			
1	0	0	7 (3)	3 (1)	*	70%	75%
2	0	1	0	2 (0)	0%	0%	*
3	1	4	2 (2)	2 (0)	20%	50%	100%
4	0	12	2 (2)	6 (0)	0%	25%	100%
5	0	0	4 (2)	3 (0)	*	57%	100%
6	2	20	10 (9)	3 (2)	9%	77%	82%
7	0	0	0	0	*	*	*
8	0	0	0	0	*	*	*
9	3	7	1 (1)	1 (0)	30%	50%	100%
10	1	7	6 (5)	7 (4)	13%	46%	56%
11	2	9	0	1 (0)	18%	0%	*
12	1	1	1 (0)	0	50%	100%	*

13	1	18	1 (1)	2 (0)	5%	33%	100%
14	7	12	10 (6)	15 (1)	37%	40%	86%
TOTALS	**18**	**91**	**44 (31)**	**45 (8)**			
MEDIAN	**1**	**6**	**2 (2)**	**2 (0)**	**15%**	**48%**	**100%**

* Impossible to calculate percentage of successful stepping attempts. Please note that the total number of initial stepping attempts (successful + unsuccessful) directly corresponds to the number of freezing episodes for each participant and condition.

DISCUSSION

This study provides preliminary evidence that a 'cha-cha' weight-shifting cue is effective to help people with PD+FOG successfully re-initiate turning when freezing. This expands findings by Maslivec et al. [13] who showed the effectiveness of similar *internally* generated weight-shift strategies during forward stepping tasks. Turning – a known trigger of freezing [14,15] – is a more complex task due to the added complexities of co-ordinating the position of the centre of mass over the changing base of support while simultaneously rotating body segments. Our results suggest that the simple cha-cha weight-shifting cue can enhance turning without compromising safety, neither during the laboratory-based assessment nor during subsequent self-reported use in daily life.

The benefits of the 'cha-cha' weight-shifting cue are likely the product of participants putting themselves in an advantageous biomechanical position and/or increased focus to movement [13]. We hypothesise that the tight coupling between both these factors contributes to the cue's effectiveness, and that linking music to associated dance movement may exploit well-learned audio-motor associations (see also [24]). Further studies are needed to investigate the longer-term effects of these and similar 'rescue' strategies, and explore the underlying mechanisms in more detail.

Despite the above, participants did not necessarily find it easy to use the cha-cha cue straightaway; overt use was evident for only 44% of stepping attempts following a freeze in the Cha-Cha Cue condition. Further, in this study, two individuals experienced FOG only during the Cha-Cha Cue condition. A potential explanation could be that the anticipation of having to use a novel strategy have increased cognitive load/attentional demands of the task, thus resulting in greater likelihood of freezing [21]. It is likely that additional training is needed for participants to fully familiarise themselves with, and internalise, the strategy and use it when required (i.e., when freezing during turning). That said, follow-up questions showed that even with this one-off 'training' session, many participants kept using the cha-cha cue in daily life, commenting that it was both a safe and (generally) effective strategy to add to their 'toolbox' [10]. Current work is underway to create online resources for people with Parkinson's and FOG to use at home, to learn and practice similar creative weight-shifting 'rescue' strategies [25].

While promising, results are qualified by two key limitations. For one, as the Baseline condition always preceded the Cha-Cha Cue condition, order effects cannot be ruled out. That is, participants may have become more at ease and familiar with the setting, potentially leading to less severe freezing, making it easier to step from a freeze. On the other hand, accumulating fatigue and/or wearing off of dopaminergic medication may counteract such effects. A second limitation relates to the subjective scoring of freezing events and stepping attempts. While the scoring system was standardised and numerous steps taken to minimise rater bias, bias could have nonetheless influenced estimates of the effects of the 'cha-cha' weight shifting cue.

In all, our results provide initial evidence for the potential utility of a simple 'cha-cha' weight shifting cue to facilitate stepping from a freeze in people with PD+FOG. Follow-up studies therefore need to

control for order effects, combine clinical (video) assessment of freezing with objective outcomes (i.e., force plate analysis of APAs), and further scrutinise the underlying mechanisms (e.g., enhanced motivation, reduced anxiety/increased confidence).

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SUPPLEMEMTARY MATERIAL 1. SCREENSHOT OF VR ENVIRONMENT

A screen capture of the virtual reality environment, showing the view down a staircase through a narrow doorway.

SUPPLEMENTARY MATERIAL 2. FOLLOW-UP QUESTIONNAIRE

Follow-Up Questions:
Thank you again for partaking in our study. We would like to ask a few follow-up questions about the study and how you have been getting on since. Please be open and honest with us because this is essential for us to improve the cueing intervention.

1. How have your experiences with freezing while turning been since partaking in the study?
   - Worsened greatly
   - Worsened slightly
   - Stayed the same
   - Improved slightly
   - Improved greatly

2. How often have you used the cue?
   - Never
   - Less than once a week
   - More than once week
   - Once a day
   - Several times a day

2a. If never: Why not?

3. Do you feel safe and comfortable while using the cue?
   - Yes
   - No
   - Any comments on this:

4. Would you recommend this cue to another person with PD?
   - Yes
   - No
   - Any comments on this:

5. Overall, how helpful do you think this cue is
   - Very unhelpful
   - Somewhat unhelpful
   - No effect
   - Somewhat helpful
   - Very helpful

6. Do you have any questions or comments about the use of the cue?

SUPPLEMENTARY MATERIAL 3. PARTICIPANT VIDEO EXCERPTS
Patient videos and associated annotations are available in this folder on OSF:
https://osf.io/wxcpe/?view_only=0e08a4120b96491189e47438e51e21cc

If accepted for publication we would like to upload the videos as supplementary files to the publication. This was not feasible yet due to file size restrictions, hence why we created a private OSF page.