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Short communication

Are individuals with Parkinson's disease capable of speech-motor learning? — A preliminary evaluation

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Introduction: The benefits of different practice conditions in limb-based rehabilitation of motor disorders are well documented. Conversely, the role of practice structure in the treatment of motor-based speech disorders has only been minimally investigated. Considering this limitation, the current study aimed to investigate the effectiveness of selected practice conditions in spatial and temporal learning of novel speech utterances in individuals with Parkinson's disease (PD).
Methods: Participants included 16 individuals with PD who were randomly and equally assigned to constant, variable, random, and blocked practice conditions. Participants in all four groups practiced a speech phrase for two consecutive days, and reproduced the speech phrase on the third day without further practice or feedback.
Results: There were no significant differences ($p > 0.05$) between participants across the four practice conditions with respect to either spatial or temporal learning of the speech phrase. Overall, PD participants demonstrated diminished spatial and temporal learning in comparison to healthy controls. Tests of strength of association between participants' demographic/clinical characteristics and speech-motor learning outcomes did not reveal any significant correlations.
Conclusions: The findings from the current study suggest that repeated practice facilitates speech-motor learning in individuals with PD irrespective of the type of practice. Clinicians need to be cautious in applying practice conditions to treat speech deficits associated with PD based on the findings of non-speech-motor learning tasks.

1. Introduction

The role of different practice conditions in limb rehabilitation of individuals with Parkinson's disease (PD) has been extensively investigated [1]. However, the role of structure of practice in speech-motor learning remains unknown in PD. As individuals with PD present with motor learning deficits [2], examining the role of practice structure in speech-motor learning is particularly relevant. The current study aimed to compare the benefits of selected practice conditions (constant, variable, random, and blocked practice) in both spatial and temporal learning of novel utterances in individuals with PD. An important aspect to be considered in pursuing this line of research is the influence of non-motor symptoms (hearing loss and cognitive impairment), and clinical/demographic characteristics, especially severity of motor impairment and age, on speech-motor learning. The current study also explored the strength of association between these variables and speech-motor learning outcomes.

2. Methods

Sixteen participants with PD (12 males & 4 females) consented to participate. They were recruited from a local branch of the New Zealand Parkinson's Society. The mean age of the participants was 70 years (range = 57–84 years). The onset of PD ranged from 4 to 12 years. All of the participants were on dopamine replacement

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therapy, but the information on Levodopa Equivalent Dosage was unavailable at the time of participant recruitment. Data for the present study were collected when participants were in a self-reported "on" state. A regional ethics committee approved the current study.

Participants did not undergo a formal audiological evaluation but none complained of difficulties in daily listening conditions. In addition, the researcher informally evaluated the participants' speech recognition by asking them to repeat 5–7 sentences produced behind them at an average conversation loudness level. All participants were able to repeat the sentences without difficulty. Participants were not given a neuropsychological assessment but the researcher informally evaluated participants' cognitive domains of recent memory, language skills, executive function, and visual spatial function by engaging participants in conversations about their recent events, involving them in a serial naming task, asking them how they would prepare to go on a vacation, and the geographical location of their house, respectively. No significant cognitive deficits were revealed. In addition to the motor subsection, the participants were also administered the cognition subsection of the Movement Disorder Society–Unified Parkinson's Disease Rating Scale (MDS-UPDRS) prior to the experiment. Except for two participants who scored '1' on the cognition subsection, all participants scored a '0', suggesting that none of the participants had significant cognitive deficits. Caregivers also did not report any concerns about the participants' cognitive abilities. Demographic details, MDS-UPDRS scores, and Hoehn and Yahr staging scores of the participants are presented in Table 1.

Participants were randomly and equally assigned to one of four practice conditions. The practice conditions were (1) constant practice, (2) variable practice, (3) blocked practice, and (4) random practice. A non-PD group of 80 healthy individuals (21 males and 59 females) in the age range of 40–80 years ($M = 59$ years) served as a comparison group [3]. These participants performed the same tasks and were grouped in a similar fashion to the PD groups. Their data are included in the present study for comparison purposes.

2.1. Speech stimuli

Participants in each of the four practice conditions were required to learn a target meaningless speech phrase "*Thak glers wur vasing veen arad moovly*". A meaningless phrase was chosen to avoid ceiling effect in learning the speech phrase. The speech phrase incorporated both spatial and temporal aspects of motor learning. Along with the target phrase, two "alternate" speech phrases were created. The first phrase contained the same non-words as the target speech phrase but varied in temporal duration. This phrase was used for the variable practice condition. The second alternate phrase was "*Ang haky deebs reciled tofently roovly*". This phrase was used for random and blocked practice conditions, which involved learning two or more motor tasks of different motor plans. For task training, the target and alternate phrases were pre-recorded by a young adult male speaker of New Zealand English.

2.2. Procedure

The experiment took place over three consecutive days. The first two days constituted the acquisition phase, and the third day served as the retention phase. Each practice session lasted 60–90 min. Participants were involved in a practice regime of 50 trials per task, during each day of the acquisition phase. Prior to the practice sessions, participants were instructed to match their productions to the target phrase as accurately as possible in terms of both spatial and temporal characteristics during the practice trials. The practice regime was carried out via a PowerPoint presentation. A total of 50 slides were used to generate 50 practice trials. Each PowerPoint slide provided an orthographic as well as an audio representation of the speech phrase. The visual and auditory representations of the speech phrase containing words as well as the word and pause durations are shown in Fig. 1. The complete production following the provision of orthographic/visual and auditory representations comprised one practice trial.

After completion of 10 consecutive trials, the researcher provided feedback to the participants regarding their spatial and temporal accuracy. Across the two consecutive days each participant received 10 instances of feedback on their phrase productions. During the retention phase, participants were required to produce the target phrase without further practice or feedback. All task attempts during the retention phase were audio-recorded for acoustic analyses. The entire retention phase lasted 10–15 min. Participants in constant practice were involved in a practice regime of 50 trials of the target phrase during each day of the acquisition phase and received feedback after every 10 trials. On the third day, participants returned for the retention phase, and reproduced 5 trials of the target phrase without any practice or feedback. Participants in variable practice condition practiced 25 trials of the target phrase and 25 trials of the alternate phrase during each day

Table 1
Descriptive data of the participants in the clinical group including age, sex, MDS-UPDRS scores, Hoehn & Yahr staging scores, and practice conditions. Mean scores are indicated at the bottom of the table. Standard deviation are indicated in parentheses.

Participants	Age	Sex	Motor UPDRS	Speech UPDRS	Hoehn & Yahr	Practice conditions
1	84	M	48	2	2	Constant
2	80	M	53	1	1.5	Constant
3	69	M	60	3	2	Constant
4	71	F	61	2	2	Constant
5	74	M	41	1	1.5	Variable
6	62	M	59	2	3	Variable
7	71	M	34	2	1.5	Variable
8	57	F	32	1	1	Variable
9	71	M	32	2	1.5	Random
10	67	M	42	2	1.5	Random
11	71	M	39	1	2	Random
12	69	M	40	1	1.5	Random
13	71	F	21	1	1	Blocked
14	58	M	61	2	2.5	Blocked
15	81	M	55	1	2.5	Blocked
16	64	M	48	1	2	Blocked
Mean (SD)	70 (7.58)		45.37 (12.2)	1.56 (0.63)	1.81 (0.54)	

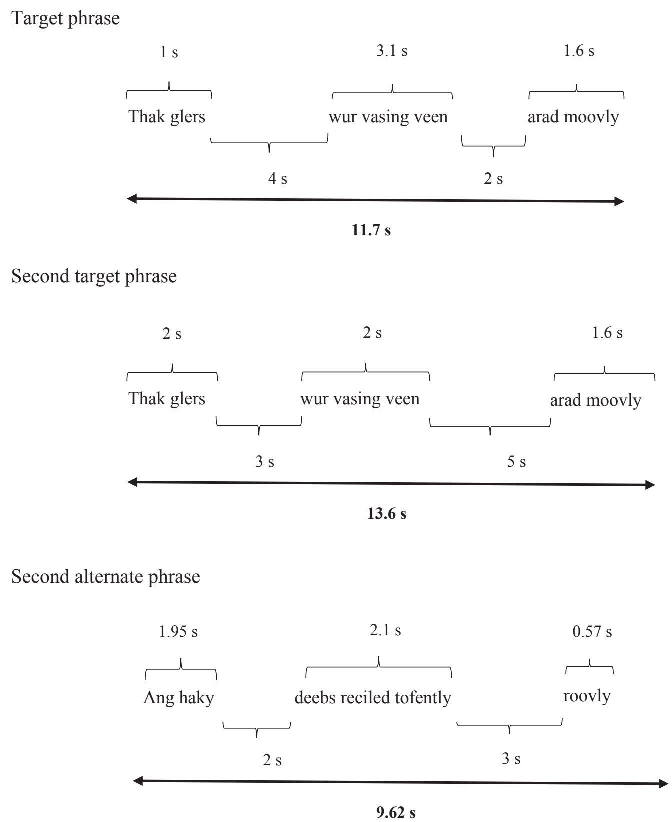

Fig. 1. Schematic representation of the target, alternate, and second alternate phrases.

of the acquisition phase, and received 5 instances of feedback trials for both the target and alternate phrases. Participants in random practice condition practiced 25 trials of the second alternate phrase in addition to 25 trials of the target phrase. Participants in blocked practice condition practiced the second alternate phrase from trials 1 through 25, and the target phrase from trials 26 through 50, and the practice order was reversed on the second day. The manner of practice, provision of feedback, and the retention phase for participants in random and blocked practice conditions was similar to that of the variable practice condition.

2.3. Analyses

Data collected during the retention phase consisted of five trials of the target phrase. Spatial analysis of the speech task focused on evaluating the production accuracy of the target speech phrase by calculating the Percentage of Phonemes Correct (PPC) [4]. The PPC was calculated by dividing the number of correct phonemes produced by the total number of phonemes produced, and multiplying by 100. A mean PPC was obtained from the final 5 retention trials of each participant, as well as a group mean for the 4 participants in each practice group. As the focus of the study was on the learning outcome of the target phrase alone, production accuracy of the alternate phrases was not evaluated.

Temporal analysis involved calculating the synchrony of participants' productions of the speech phrase during the final five retention trials in comparison to the original target phrase. Participants' productions during the retention trials, as well as the original example of the target phrase, were fed into the Audacity acoustic analysis software. The software displayed the original example of the target phrase on the top panel of the computer screen; the bottom panel displayed the participants' productions. The onset point was same for the productions and the original waveforms. The offset point of the production waveforms was based on offset of the original target waveform. The temporal synchrony between the original examples and the participants' production was calculated through phi correlation using a MATLAB-based program. A mean phi correlation was obtained from the final five responses for each participant. A grand mean phi correlation value was calculated for the PD participants in each of the four practice conditions, respectively.

Spatial and temporal learning among participants in the four practice conditions was compared by subjecting PPC values and phi correlation values, respectively to a Kruskal-Wallis H test. Pearson correlation was used to calculate intra-rater reliability by randomly choosing 20% of the data. Intra-rater reliability of spatial and temporal analyses was $r = 0.95$ and $r = 1.00$, respectively. All correlations were significant ($p < 0.01$).

To assess the influence of non-motor symptoms and demographic/clinical characteristics on speech-motor learning, the strength of association between the scores obtained on the cognition, motor and speech UPDRS subsections, participants' age and speech-motor learning outcomes (PPC and Phi correlation) were examined through Kendall's Tau Correlation.

3. Results

3.1. Spatial learning

The mean PPC values of the participants in the four practice conditions are shown in Table 1. Results revealed there were no significant differences in spatial learning between participants across four practice conditions, $\chi^2(3) = 0.90$, $p = 0.8$. For comparison purposes, the previously reported results for non-PD participants are also shown in Table 1. Similar to the present results, non-PD participants did not differ significantly between practice conditions. However it is noteworthy that, while the PD participants generally performed in the range of 72–78%, the non-PD groups showed a higher percentage of retention, with the exception of the blocked practice condition.

3.2. Temporal learning

The mean phi correlation values are shown in Table 1. Results of Kruskal-Wallis H test found no significant differences in temporal learning between participants of the four practice conditions, $\chi^2(3) = 1.15$, $p = 0.76$. Past results for non-PD participants are listed in Table 2. Non-PD participants also did not differ significantly on temporal learning according to type of practice. In comparison to the non-PD group, the phi coefficient values for the PD group were lower for each practice condition.

3.3. Strength of association

Kendall's Tau Correlation revealed no correlations between either non-motor symptoms or clinical/demographic characteristics and speech-motor learning outcomes.

4. Discussion

Our results revealed that individuals with PD do not differ on spatial learning based on the structure of practice. A similar result was found by Kaipa [3] who investigated the role of constant, variable, random, and blocked practice conditions in spatial learning of novel utterances among healthy individuals. This contradicts findings of non-speech-motor learning studies where variable and random practice are superior to constant and blocked

Table 2
Mean PPC values (%) and phi correlation values for the PD groups. Data previously reported for non-PD participants (Kaipa [3]) are also included. Standard deviations are reported in parentheses.

Groups/Practice conditions	Constant	Variable	Random	Blocked
PPC values				
PD group	78.1 (25.7)	72.5 (9.1)	74.8 (21.3)	77.55 (17.8)
Non-PD group	91.6 (11)	86.8 (14.9)	91.1 (10.4)	77.5 (25.1)
Phi correlation values				
PD group	0.13 (0.06)	0.10 (0.17)	0.05 (0.06)	0.09 (0.20)
Non-PD group	0.34 (0.18)	0.21 (0.21	0.21 (0.16)	0.22 (0.19)

practice conditions, respectively [5–7]. Typically, findings in the non-speech-motor learning literature have been based on tasks that rely on procedural memory (e.g., shooting a basketball) [8]. However, learning novel utterances involves episodic and semantic memory [8]. It is possible that superiority of variable and random practice cannot be generalized to speech-motor learning and may be only applicable to non-speech-motor learning tasks. Comparison of the PPC values of the PD participants and the healthy participants in Kaipa [3] suggests that individuals with PD demonstrated reduced capacity for spatial learning. Past studies have revealed that individuals with PD demonstrate decreased spatial speech coordination in the form reduced lip and jaw peak velocities due to underlying bradykinesia [9]. Consistent with findings in the motor learning literature [1], results of the present study suggest that individuals with PD are capable of spatial learning, but is reduced in comparison to healthy individuals. Due to inherent problems in motor learning, it is likely that the structure of practice does not influence spatial learning in individuals with PD.

Similar to spatial learning, participants with PD did not differ in temporal learning based on practice structure. Again these findings are similar to Kaipa [3], who also found that temporal learning of a novel utterance is not influenced by the structure of practice. Even though, it is not possible to compare the PPC values and phi correlations directly, results suggest that PD participants performed poorly on temporal learning in comparison to spatial learning. It is common for patients with PD to have problems with dual task performance due to the bidirectional interference (i.e. the performance of one task simultaneously interferes with the performance of another task) [10]. It is possible that the participants would have chosen to sacrifice temporal over spatial learning as they found it difficult to focus on both the tasks. Comparison of the phi correlation values of the PD participants to healthy participants revealed that PD participants demonstrated poorer temporal learning ability. It is well known that deficits in basal ganglia disorders affect movement speed and rhythm of speech [11]. The speech timing deficits due to the impaired motor planning ability at the syllable and phrase levels could possibly explain the decreased temporal learning in participants with PD in comparison to the control group participants.

Although there was no significant correlation between the non-motor symptoms, clinical/demographic characteristics, and speech-motor learning outcomes, the role of these variables on speech-motor learning cannot be overlooked. It is also possible that the small sample size did not offer adequate statistical power to reveal any association between these variables. Furthermore, research suggests that individuals with PD are at a higher risk for peripheral high-frequency hearing loss [12,13], but there have been conflicting results with regard to central auditory processing deficits [12]. Although participants in the current study reported no overt hearing or speech recognition difficulties, it is difficult to rule out peripheral as well as central auditory deficits in these individuals without a comprehensive audiological evaluation. It is possible that auditory deficits in individuals with PD can result in speech perception and production problems, thereby influencing speech-motor learning outcomes.

Similarly, even though the cognition scores of MDS-UPDRS, informal cognitive evaluation as well as the reports of participants/caregivers did not reveal significant cognitive deficits among participants, the presence of cognitive deficits should be ideally ruled out based on the performance on a battery of neuropsychological tests such as Wisconsin Card Sorting Task, Clock copying test, Tests of verbal and non-verbal memory, and Stroop test. Mild cognitive impairment (MCI) is common in PD [14] and it is possible that the cognition subsection of MDS-UPDRS and the informal evaluations would not have been sensitive to identify MCI in patients with PD in the current study. As learning novel non-words (as in the current study) requires intact episodic and semantic memory, it is possible that participants with MCI would have found this learning task to be challenging. Future larger studies should aim to systematically investigate the role of non-motor symptoms such as hearing loss and cognition on speech-motor learning in individuals with PD.

5. Conclusion

To our knowledge this is the first study to have systematically investigated speech-motor learning in individuals with PD as a function of practice condition. Despite the small sample size and some limitations, this study revealed some interesting findings worthy of confirmation and further exploration in larger studies. First, individuals with PD are capable of speech-motor learning, but the extent of speech-motor learning is diminished in comparison to healthy controls. Second, no particular type of practice is superior to other types of practice for speech-motor learning in PD, which is contrary to what has been found for non-speech-motor learning. Thus, from a treatment perspective, clinicians need to be cautious in applying practice conditions to treat speech disorders based on the findings of non-speech-motor learning tasks.

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