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Effect of concurrent walking and interlocutor distance on conversational speech intensity and rate in Parkinson's disease

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ABSTRACT

Previous studies have demonstrated a negative effect of concurrent walking and talking on gait in Parkinson's disease (PD) but there is limited information about the effect of concurrent walking on speech production. The present study examined the effect of sitting, standing, and three concurrent walking tasks (slow, normal, fast) on conversational speech intensity and speech rate in fifteen individuals with hypophonia related to idiopathic Parkinson's disease (PD) and fourteen age-equivalent controls. Interlocuter (talker-to-talker) distance effects and walking speed were also examined. Concurrent walking was found to produce a significant increase in speech intensity, relative to standing and sitting, in both the control and PD groups. Faster walking produced significantly greater speech intensity than slower walking. Concurrent walking had no effect on speech rate. Concurrent walking and talking produced significant reductions in walking speed in both the control and PD groups. In general, the results of the present study indicate that concurrent walking tasks and the speed of concurrent walking can have a significant positive effect on conversational speech intensity. These positive, "energizing" effects need to be given consideration in future attempts to develop a comprehensive model of speech intensity regulation and they may have important implications for the development of new evaluation and treatment procedures for individuals with hypophonia related to PD.

1. Introduction

Parkinson's disease (PD) is a progressive neurological disorder characterized by resting tremor, muscle rigidity, slowness of movement, reduced range of motion, gait disturbance and postural instability [1]. It is estimated that 60–80% of individuals with PD will develop a speech impairment referred to as hypokinetic dysarthria [2]. A common speech symptom in PD is low speech intensity or hypophonia. Hypophonia is often the first speech symptom to emerge in the early stages of the disease and it is associated with a reduction of about 2–5 decibels (dB) in speech intensity relative to healthy older adults [3]. Like many of the other motor symptoms in PD, hypophonia is hypothesized to be causally related to a sensory deficit or a sensorimotor integration deficit that involves the abnormal perception of loudness and/or the abnormal integration of loudness-related auditory feedback during the normal regulation of speech intensity [4]. One approach to investigating these sensorimotor deficit hypotheses is to examine the effect of changes in sensory feedback on speech intensity and to systematically manipulate the sensorimotor conditions that are known to modulate speech intensity.

Several studies have examined speech intensity modulating conditions and contexts in PD [3,5–7]. PD participants have been found to respond to increases in interlocutor distance (distance between talkers) or increases in background noise by increasing speech intensity in a manner that is similar to that of controls [3,5]. These results suggest that individuals with PD demonstrate relatively normal patterns of intensity regulation despite a consistent overall reduction in the "gain" parameter of speech intensity control. In contrast, performing a concurrent limb and speech movement task has been found to have an inconsistent effect on speech intensity in PD participants [3,7]. For example, Ho et al. [7] examined the effect of a concurrent manual visuomotor tracking task on the intensity of speech during conversation and a loud counting task. This concurrent task produced a significant decrease in speech

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intensity for the loud counting task but not the conversational speech task. On the other hand, Adams et al. [3] found that a similar concurrent manual visuomotor tracking task was associated with a significant increase in conversational speech intensity in the PD participants but not the controls. The authors suggested that certain concurrent tasks might have an "energizing effect" on speech intensity in individuals with hypophonia related to PD. It was further suggested that the nature of the concurrent task may play an important role in the modulation of speech intensity in PD [3].

Walking and talking is a potentially important concurrent task in PD. Gait disturbance is a common symptom in PD and frequently co-occurs with speech impairment [8]. Gait and speech disturbances are classified as axial PD symptoms that may share unique and common neurodegenerative processes [9]. Previous concurrent speech and gait studies have consistently reported a negative effect on walking performance in PD [10,11]. In addition, it appears that as the demands of the speaking condition increase, there is a greater negative effect on gait and an increased risk of falls [12]. The effect of concurrent walking on speech intensity, or other aspects of speech production, has not been described in previous studies of PD.

The primary objective of this study was to examine the effect of concurrent walking tasks on conversational speech intensity and rate in PD, the second objective was to examine the effect of changes in interlocutor distance on speech intensity and rate in PD, and the third objective was to examine the effect of concurrent talking on walking speed in PD.

2. Methods

2.1. Participants

This study included 15 participants (2 F, 13 M) between 58 and 80 years old ($M = 72.07$) that were identified and diagnosed with mild to moderate idiopathic PD and hypophonia by a neurologist. In all PD participants, hypophonia was the primary speech symptom. Parkinson severity scores, obtained with the Unified Parkinson Disease Rating Scale (part 3), ranged from 10 to 45 out of a maximum severity of 108 ($M = 25.7$; SD = 10.2). Only PD participants with mild gait impairment were included in the study. Duration of PD ranged from 1 to 17 years ($M = 8.7$; SD = 6.2). PD participants were stabilized on their anti-Parkinson medications, and tested approximately one hour after taking their regular medication. Three PD participants were not on anti-Parkinson medication. All PD participants passed ($M = 28.8$, $SD = 1.4$) a cognitive screening (Mini Mental Status Examination). The study also included 14 age-equivalent healthy control participants (7 M, 7 F) between 59 and 82 years old with no history of speech or gait impairments. The study was approved by the local Health Sciences Research Ethics Board at Western University and all participants provided written informed consent.

2.2. Instruments

Participants wore a belt pack containing an audio recorder (M-audio Microtracker II) that was connected to a head-mounted microphone (DPA 4060) positioned 6 cm from the mouth. The headset microphone was calibrated with an audio signal (70 dBA SPL) and a sound level meter placed at 15 cm from the participant's mouth [13]. A video camera was placed perpendicular (Panasonic HC-V700) to a walking path (1 m× 21 m) and was used to record each participant's walking performance.

2.3. Procedures

Participants performed several concurrent and non-concurrent speech and walking conditions. Speech conditions involved engaging in a conversation with the experimenter for approximately 3 min about a familiar topic. The topics included favorite vacations, interests, hobbies, relatives, occupational experiences, etc. The conversations took place with the participant positioned at an interlocutor distance of 1 and 6 m. The five walking conditions included, (1) sitting, (2) standing, (3) walking at a habitual speed, (4) walking at a speed perceived to be two times slower than the habitual speed, and (5) walking at a speed perceived to be two times faster than habitual. During all walking conditions the examiner walked alongside the participant (at 1 or 6 m) and tried to follow, rather than lead, the participant's walking pace. No instructions were given with regard to the focus of attention on walking or talking.

2.4. Measures and statistical analysis

Speech recordings were analyzed using the acoustic waveform editing and analysis functions in the Praat software [14]. The two primary speech measures included: average speech rate (words per minute) and average speech intensity (dB SPL). The first ten conversational utterances (minimum five words in length and excluding dysfluencies) were analyzed from each experimental condition. Following a re-measurement of 20% of the data by two examiners, the average inter-judge ($r = 0.90$) and intra-judge ($r = 0.92$) reliability for the combined speech intensity and rate measures were found to be significant ($p = 0.001$).

Walking speed was obtained from the video recordings by manually counting the number of steps in each 21-m walking segment and measuring duration (speed = 21 m/duration). The speech intensity, speech rate and walking speed data were examined with separate three-way ANOVAs.

3. Results

3.1. Conversational speech intensity

Results related to conversational speech intensity are presented in Table 1 and Figs. 1 and 2. Across all of the experimental conditions, the participants with PD had an average speech intensity level that was significantly lower (−4.1 dB) than controls [$F(1, 21) = 11.322$, $p = 0.003$]. The increase in interlocutor distance was associated with a significant increase in speech intensity (+2.5 dB) [$F(1, 21) = 103.233$, $p = 0.000$]. There was a significant effect of the walking tasks on speech intensity [$F(4, 21) = 58.406$, $p = 0.000$].

In general, the post hoc analysis (Bonferonni corrected *t*-tests; 0.05/10 = 0.005) revealed that the normal and fast walking conditions had significantly higher speech intensity than the sitting and standing conditions. In particular, the PD and control groups had significantly higher speech intensity while walking at a normal speed than while standing and talking at an interlocutor distance of 1 m ($p < 0.005$) and 6 m ($p < 0.005$). In addition, both

Table 1
Average conversational speech intensity at 1 and 6 m interlocutor distances across walking conditions for the control and PD participants.

	1 m		6 m		
	Control	PD	Control	PD	Mean
Sitting	69.7 (2.6)	65.5 (3.5)	72.9 (2.2)	68.6 (3.6)	69.1 (2.9)
Standing	69.3 (2.6)	64.2 (3.8)	72.2 (2.5)	68.0 (3.5)	68.4 (3.1)
Walking slow	71.3 (2.5)	67.6 (4.5)	74.1 (2.8)	70.3 (3.4)	70.8 (3.3)
Walking normal	71.8 (2.4)	68.2 (3.2)	74.3 (2.4)	70.2 (3.1)	71.1 (2.7)
Walking fast	73.4 (2.8)	69.7 (3.4)	75.7 (3.0)	70.8 (3.3)	72.4 (3.1)
Mean	71.1 (2.5)	67.04 (3.7)	73.8 (2.6)	69.6 (3.3)	

Note: Speech intensity levels are in dB SPL. Standard deviations appear in parentheses beside means.

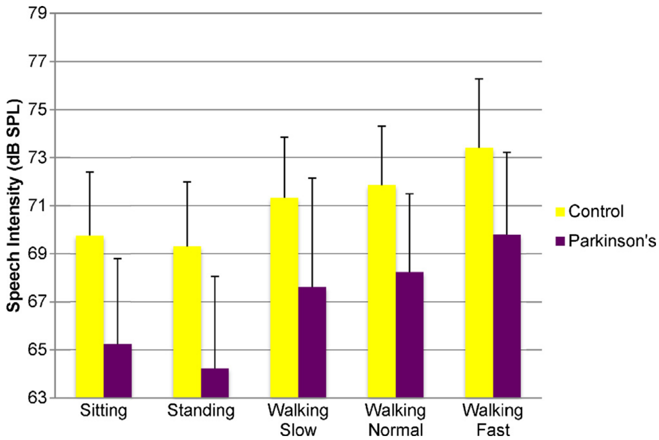

Fig. 1. Average conversational speech intensity for the Parkinson and control groups obtained for the five walking conditions at an interlocutor distance of 1 m.

the PD and control groups had significantly higher speech intensity while at a normal speed than while sitting and talking at an interlocutor distance of 1 m ($p < 0.005$) and 6 m ($p < 0.005$). A similar pattern of significant post hoc results were obtained for the comparisons involving the fast walking rate and the standing or sitting conditions. The fast walking conditions were always associated with significantly higher speech intensity in both groups.

For the post hoc comparisons involving the three walking conditions (Bonferonni corrected *t*-tests; 0.05/3 = 0.016), the fast walking condition was associated with significantly higher speech intensity than the normal and slow walking conditions for both the PD and control groups at the 1 m interlocutor distance. For these specific comparisons, the PD and control groups had significantly higher speech intensity during the fast walking condition than the normal walking condition ($p < 0.016$) and a significantly higher speech intensity during the fast walking condition than the slow walking condition ($p < 0.016$). At the 6 m interlocutor distance, the fast walking condition was also associated with significantly higher speech intensity for the control group but not for the PD group.

There was a significant interaction between walking conditions and the interlocutor distance conditions [$F(4, 21) = 4.067$, $p = 0.005$]. This indicates that the relative changes in speech intensity across the five walking conditions were greater at the 1 m than the 6 m interlocutor distance for both the PD and control groups.

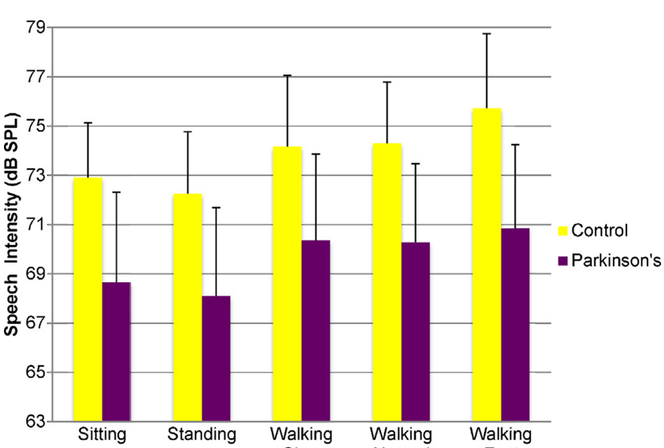

Fig. 2. Average conversational speech intensity for the Parkinson and control groups obtained for the five walking conditions at an interlocutor distance of 6 m.

3.2. Conversational speech rate

The results for the conversational speech rate revealed that the main effects for the group [$F(1, 20) = 0.409$, $p = 0.530$], interlocutor distance [$F(1, 20) = 0.361$, $p = 0.555$], and walking condition factors [$F(4, 20) = 0.383$, $p = 0.820$] were not significant. Thus, there was no significant difference in speech rate across the PD and control groups or the experimental conditions. Across the experimental conditions, the average speaking rate was 223 words per minute (SD = 26.1) for the controls and 231 words per minute (SD = 40.0) for the PD participants.

3.3. Walking speed

The walking speed results related to the concurrent talking and not talking conditions are shown in Table 2. The main effect of group was significant and indicates that the control group had a significantly faster walking speed (19%) than the PD group [$F(1, 26) = 15.179$, $p = 0.001$]. The main effect of walking condition was also significant [$F(2, 26) = 286.104$, $p = 0.000$] and confirms that both participant groups increased their walking speed across the slow to fast walking conditions. Finally, the main effect of concurrent talking was significant [$F(1, 26) = 49.349$, $p = 0.000$] and indicates that both participant groups walked about 11% slower while concurrently talking and walking, than while walking and not talking.

The result for the walking condition by group interaction was significant [$F(2, 26) = 20.019$, $p = 0.000$]. This indicates that the control group showed a relatively greater increase in walking speed, than the PD group, as the intended walking speed conditions increased from slow to fast. The result for the talking condition by group interaction was not significant [$F(1,26) = 3.236$, $p = 0.084$]. This non-significant result indicates that concurrent talking while walking had a similar effect on walking speed in both groups. The result for the walking condition by talking condition interaction was significant [$F(2, 26) = 7.876$, $p = 0.001$]. This indicates that concurrent talking had a greater effect on reducing the walking speed of the fast walking condition than the slower walking conditions. Concurrent talking had a limited effect on walking speed during the slow walking condition.

The main effect of interlocutor distance on walking speed was not significant [$F(1, 23) = 0.926$, $p = 0.346$] and suggests that walking speed was not affected by the change in interlocutor distance.

4. Discussion

PD participants produced a conversational speech intensity that was on average 4 dB lower than that of the controls. This is consistent with previous studies of hypophonia in PD [3,5,6,15]. Such a reduction would be very apparent to most listeners as it would reflect about a 40% drop in the perceived loudness of speech.

Despite a general reduction in speech intensity, PD participants showed a significant response to changes in interlocutor distance. Both PD and control participants had about a 2.5 dB increase in intensity as they moved from the one to the 6 m interlocutor distance. The failure to find a significant group by interlocutor distance interaction suggests that PD participants demonstrated a normal pattern of intensity regulation in response to changes in interlocutor distance. This finding is consistent with the previous interlocutor distance studies in PD [3,5,6] and provides additional support for the 'gain reduction hypothesis' in PD hypophonia [5,6]. This hypothesis suggests that there is a generalized reduction in the gain of the speech intensity generating system (i.e. a specific impairment in the gain mechanism) despite intact and normal

Table 2
Average walking speed for each walking condition during the not talking and concurrent talking conditions for the control and Parkinson participants.

	Control		PD		
	Not talking	Talking	Not talking	Talking	Mean
Walking slow	0.855 (0.166)	0.831 (0.148)	0.866 (.215)	0.748 (0.192)	0.825 (0.180)
Walking normal	1.410 (0.122)	1.258 (0.189)	1.149 (0.255)	0.943 (0.227)	1.190(0.198)
Walking fast	1.839 (0.151)	1.693 (0.145)	1.459 (0.242)	1.239 (0.323)	1.55(0.215)
Mean	1.368 (0.146)	1.26 (0.160)	1.15 (0.237)	0.976 (0.247)	

Note: Walking speed values are in meters per second. Standard deviations appear in parenthesis beside means.

processes related to the regulation of intensity in response to typical modulating conditions such as changes in the level of background noise or interlocutor distance.

The main result of this study was the finding that both the PD and control groups had significantly greater conversational speech intensity during walking conditions relative to the sitting/standing conditions and that speech intensity increased as the participants increased their walking speed. This result appears to provide support for the energizing hypothesis [3]. This hypothesis proposes that some concurrent movements or behaviors can have an 'energizing effect' that causes speech intensity to increase [3]. The hypothesis proposes that there is a spread of activation or energy from one concurrent task to another. This energizing effect, which was previously observed in concurrent manual tasks, appears to extend to concurrent walking tasks [3,16,17]. In addition, the fast walking results suggest that increasing the speed of a concurrent task may increase the energizing effect on speech intensity. Further studies are required to determine if this energizing effect is specific to changes in movement speed or reflects other more general processes, such as increased effort or increased attentional focus. The energizing effect observed in the present study may share features with the 'attentional burst effect' that has recently been described to occur in some dual task memory experiments [18]. It should be noted that the energizing hypothesis is in direct contrast to other hypotheses that have been developed to explain the detrimental or interference effects that can occur in many concurrent tasks (i.e. capacity-sharing, time-sharing, bottleneck, functional distance, etc.) [19,20]. The present results, combined with previous studies [3,16,17] indicate the need to develop new hypotheses for the special circumstances where a concurrent task has an enhancing or positive effect, as opposed to a negative effect, on speech and other behaviors.

The absence of a significant group effect for speech rate is consistent with previous studies of PD [21,22]. Previous studies suggest that a small proportion of individuals with PD (6–13%) demonstrate an abnormally rapid speech rate, however most previous studies have found that speech rate in PD is comparable to that of age-equivalent controls [2]. Although bradykinesia (slowness of movement) is a major limb symptom in PD, it is a very uncommon speech symptom and appears to provide support for the concept of significant divergence in the limb and speech motor control systems [23].

The failure to find an effect of concurrent walking on speech rate was unexpected. Based on previous studies showing speed-related entrainment in concurrent manual tasks, it was anticipated that there would be entrainment effects involving walking rate and speech rate [24,25]. It was also anticipated that concurrent walking would have effects on both speech intensity and speech rate. This dissociation between intensity and rate indicates that additional studies are required to examine the effect of concurrent walking on other speech parameters (i.e. pitch, amplitude of speech movements).

The observation that the PD participants had a slower walking speed than the control participants is consistent with previous studies [11,26,27]. Both the PD and control groups increased their walking speed across the slow to faster walking speed conditions. The significant walking speed by group interaction indicates that the PD group and the control group regulated walking speed differently across walking speed conditions. This difference may be related to limitations in the PD participants' capacity to walk fast (i.e. ceiling effect) which may have led to a relatively smaller shift in their walking speed as they moved from their normal to the fast walking conditions.

The introduction of concurrent talking produced a significant reduction in walking speed for both PD and control groups and this finding is consistent with previous studies [10,11,28]. Of potential importance was the non-significant group by talking condition interaction. This finding indicates that there was a relatively similar (negative) effect of talking on the walking speed in the PD and control participants. This finding is not consistent with most of the previous walking and talking studies which found that PD participants demonstrated a relatively greater reduction in walking speed than control participants [10,11]. Perhaps the severity of PD or the presence of cognitive impairments played a role in these inter-study inconsistencies. A potential limitation of the present study is the inclusion of participants with only mild-moderate PD and no evidence of cognitive impairment. Future studies should examine a wider range of PD severity and include individuals with specific cognitive deficits that are determined from a complete neuropsychological evaluation rather than a simple screening test such as the MMSE [29]. Another potential limitation of the present study is the use of a fairly rudimentary video-based method for measuring walking speed. Future studies involving a more sophisticated gait analysis procedure may reveal additional interactions between speech and gait metrics.

In general, the present results indicate that concurrent walking tasks and the speed of concurrent walking can have significant positive effects on conversational speech intensity in control participants and individuals with hypopohonia and PD. These effects need to be given consideration in future attempts to develop comprehensive models of speech intensity regulation in PD. The positive 'energizing' effect of concurrent walking on speech intensity may have important implications for the development of new evaluation and treatment procedures for individuals with hypophonia related to PD.

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Conflict of interest statement

There are no conflicts of interest for any of the authors.

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