Effects of speaking task on bidirectional dual-task interference in individuals with Parkinson disease

Jason Whitfield[1], Ph.D., Zoe Kriegel[1], B.S., Michaela Natal[1], Adam Fullenkamp[2], Ph.D., Daryush Mehta[3,4], Ph.D., & Anna Gravelin, M.S.[1]
[1]Communication Sciences and Disorders, Bowling Green State University;
[2]Human Movement, Sport, & Leisure Studies, Bowling Green State University;
[3]Center for Laryngeal Surgery and Voice Rehabilitation, Massachusetts General Hospital; [4]Department of Surgery; Harvard Medical School

Introduction

In addition to speech impairments, individuals with Parkinson disease (PD) often experience difficulty performing more than one motor-oriented task simultaneously, such as walking while talking (dual-task interference). Though data suggest that performance of concurrent (i.e., simultaneous) motor tasks affect speakers with PD (e.g., Bunton & Keintz, 2008; Dromey et al., 2010), the extent to which speech task difficulty affects dual-task interference between speech and non-speech motor tasks has not been fully clarified. The aim of this study was to examine the extent to which the speaking task affected bidirectional dual-task interference in individuals with PD compared to healthy controls.

Method

Participants and Protocol: Twenty-four participants, 13 participants with PD and 11 older adult (OA) controls, completed the informed consent process and participated in the current study. As outlined in Figure 1, participants produced two reading and two extemporaneous narrative samples under both single-task, speech only conditions, and while simultaneously performing a simple oscillatory motor task. The secondary task was performed in isolation (ST) and while speaking (DT) and involved drawing continuous counterclockwise circles on a digitizer tablet using the dominant hand. Speech samples were collected using a head-mounted microphone and high-quality USB interface (Sampling Rate: 44.1 kHz). Data from the digitizer tablet were collected using MovalyzeR (NeuroScript; Sampling Rate: 132 Hz).

Acoustic Analysis: Speech samples were segmented into speech runs using PRAAT, defined as a sounded interval bounded by silent intervals lasting at least 150 ms. Articulation rate of each speech run was calculated by dividing the number of syllables produced in each run by the duration.

First and second formant frequencies were extracted every 10 ms using a Kalman-based autoregressive modeling approach (Mehta et al. 2012) to calculate the Articulatory-Acoustic Vowel Space (AAVS). Outliers in the formant histories were then identified and removed and the formant traces were low-pass filtered (10 Hz). The AAVS is a measure of working formant space for an entire utterance, and was calculated as the square root of the generalized variance of the product of the F1 variance, F2 variance, and proportion of the unshared variance (Whitfield & Goberman, 2014). An example visual representation of the AAVS is shown in Figure 2.

Handwriting Analysis: The digitized handwriting traces were low-pass filtered (10 Hz) and segmented into up- and down-strokes based on a null in the vertical velocity. Example handwriting traces for a participant in the PD group and a control participant are shown in Figure 3. The position of each circular path was re-centered, and the mean and standard deviation of the vertical and horizontal range of motion was calculated for each up and down stroke. Additionally, the peak frequency and frequency spread were obtained from a spectrum (FFT) of the movement trace. The frequency spread was defined as the 90% area under the FFT curve around the median frequency. Therefore, the metrics outlined in the current study characterized the average range and frequency of the movement trace, as well as within-trial variability.

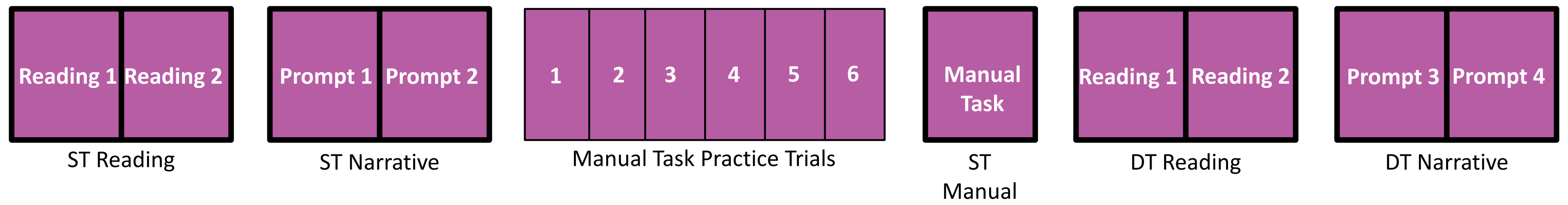

Figure 1. Sequence of the experimental protocol. Participants completed two, single-task (ST), speech only readings (ST Readings) followed by two extemporaneous narratives (ST Narratives). This was followed by six, 15-second practice manual trials to ensure that participants were comfortable performing the task. Participants then completed one ST trial of the manual task that was comparable in duration to the ST narrative task. Finally, the speakers performed the tasks under dual-task (DT) conditions. The manual task was performed while the participant read the passages (DT Reading) and performed two additional narrative samples (DT Narrative).

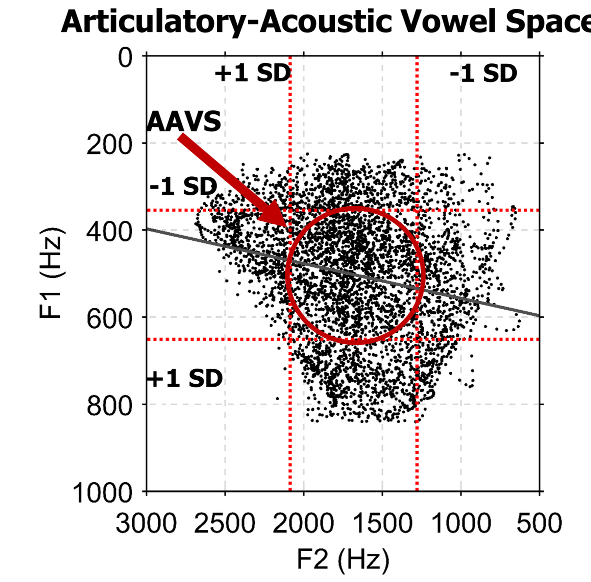

Figure 2. Visual representation of the Articulatory-Acoustic Vowel Space metric.

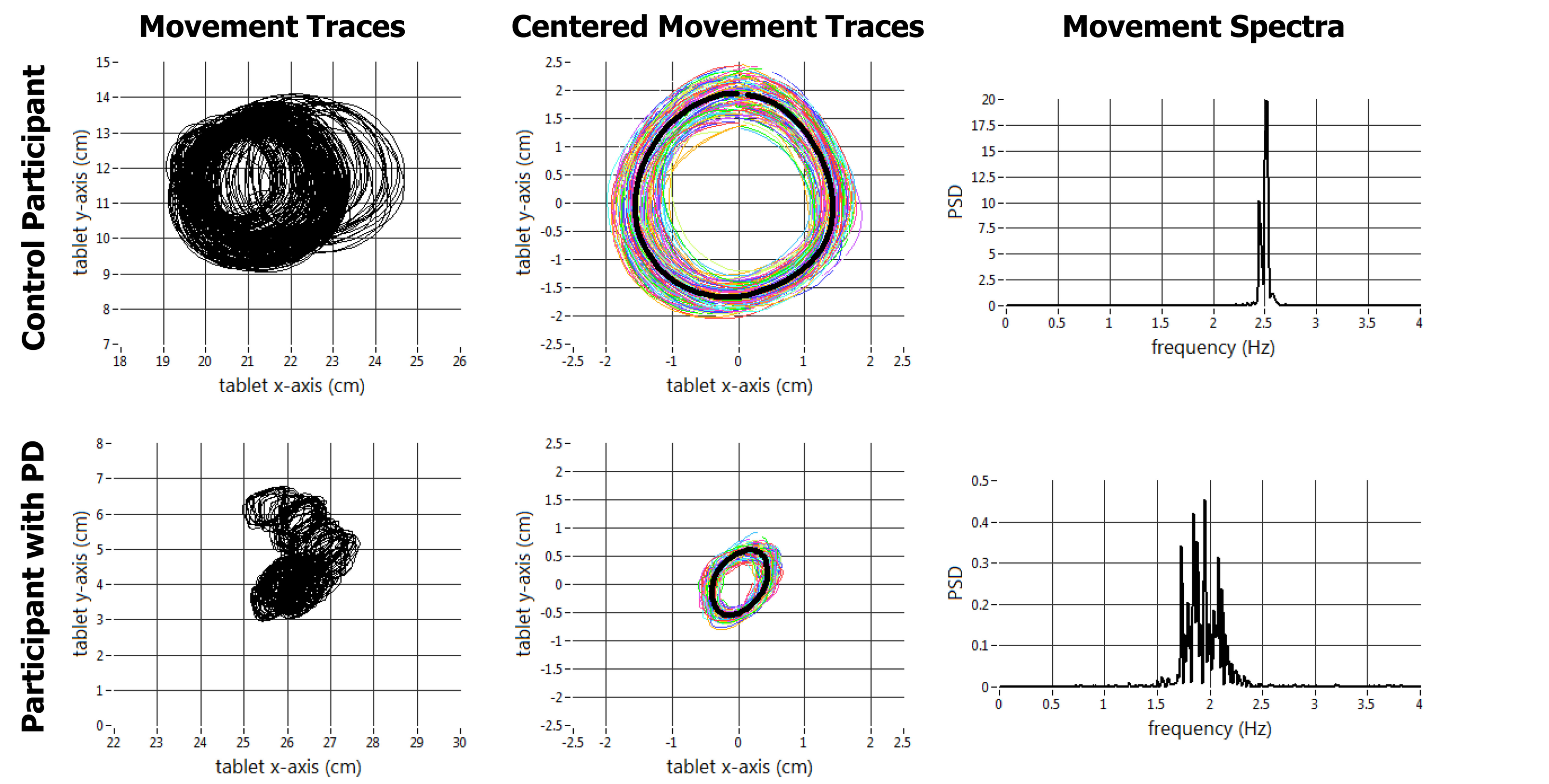

Figure 3. Example handwriting traces for one older adult control (top panes) and one participant with PD (bottom panes). The left panes show the raw tablet traces. The center panes show the centered traces. The right panes show the spectra of the movement traces demonstrating the peak movement frequencies and variation in the spectral peak.

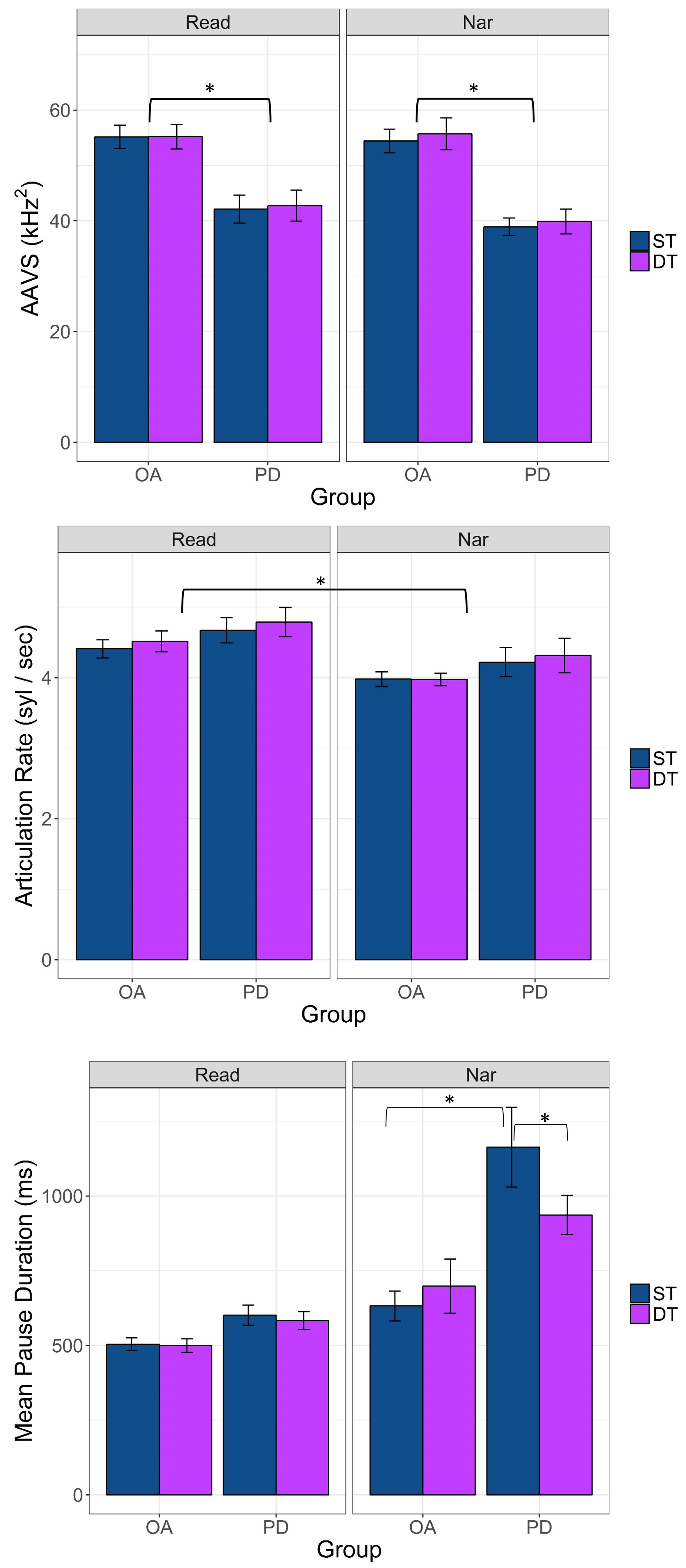

Figure 4. Means and standard errors for Articulatory-Acoustic Vowel Space (AAVS; top pane), articulation rate (middle pane), and mean pause duration (bottom pane) for the older adult control group (OA) and Parkinson disease group (PD) in the single-task (ST) and the dual-task (DT) conditions performing the reading (Read) and narrative (Nar) tasks.

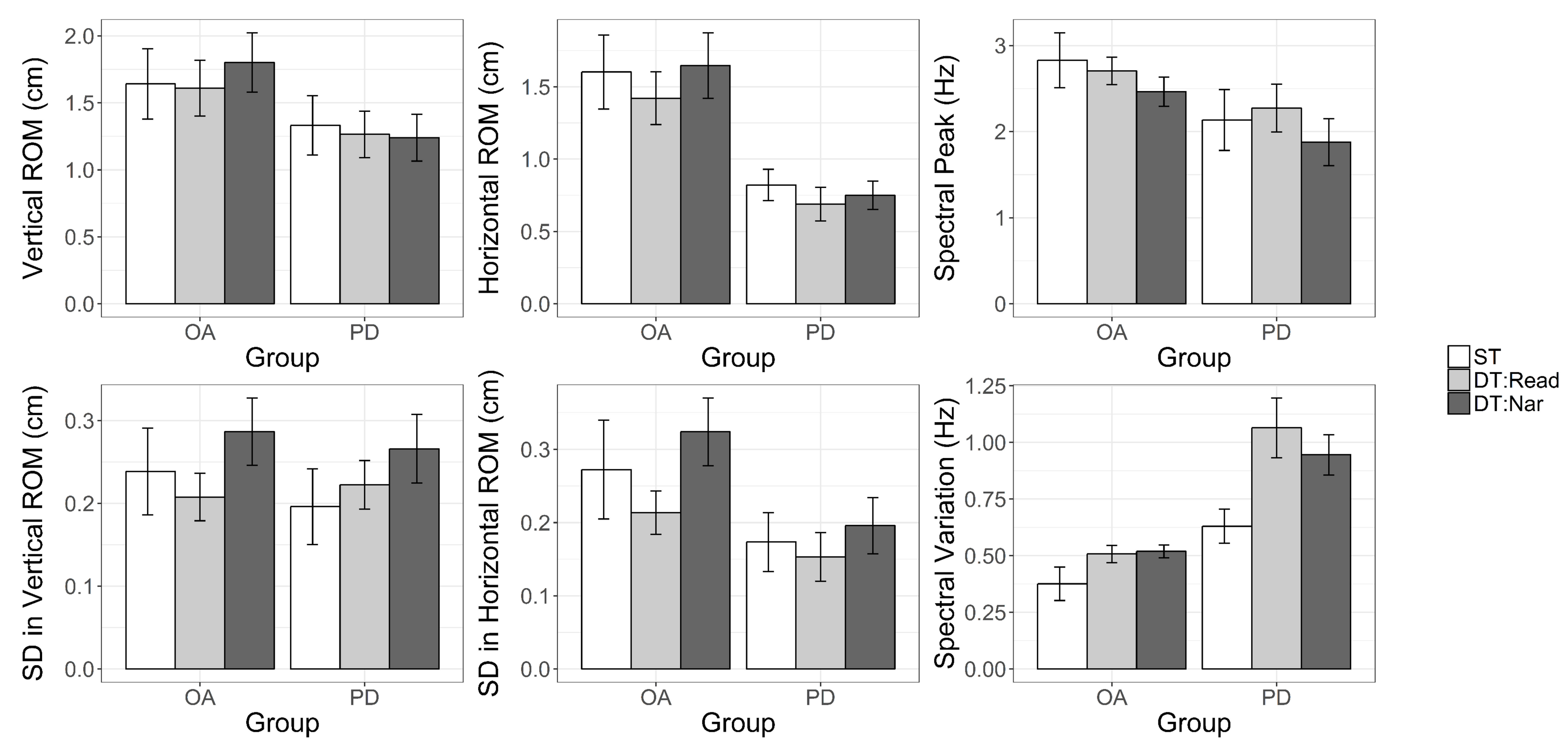

Figure 5. Means and standard errors for the kinematic metrics of the secondary manual task for the single-task (ST) and dual-task (DT) conditions that included the reading (Read) and extemporaneous narrative (Nar) tasks performed by the Parkinson disease (PD) and control (OA) group. Kinematic metrics include average range of motion (ROM) in cm for both the vertical (top left) and horizontal (top center) dimensions and Peak spectral frequency in Hz (top right), as well as the variability of the vertical (bottom left) and horizontal (bottom center) range of motion and spectral peak (bottom right).

Results and Discussion

Summary of the Speech Task Performance

Articulatory-Acoustic Vowel Space (AAVS)

- Across all tasks and conditions, speakers with PD exhibited smaller working vowel space areas than controls, $p=0.004$.

Articulation Rate

- Across both groups and conditions, speakers used a slower articulation rate in the extemporaneous speech tasks than in the reading tasks, $p=0.01$.

Pause Duration

- Speakers with PD exhibited significantly longer pause durations than controls in the narrative condition, $p=0.001$.
- Additionally, speakers with PD exhibited a significant decrease in pause duration from the single- to the dual-task condition when performing the narrative task, $p<0.001$.

Summary of Manual Task Performance

Range of Motion

- Participants with PD exhibited decreased range of motion in the horizontal, $p<0.001$, and vertical, $p=0.03$ dimensions compared to controls.

Spectral Peak Movement Frequency

- Participants with PD exhibited a lower peak movement frequency in the single-task condition than controls, $p<0.05$.

Variation in Range of Motion

- Participants with PD exhibited significantly less variation in range of motion for cycle to cycle movement in the horizontal dimension than controls, $p<0.001$.
- Control speakers exhibited greater variation in the range of motion (both vertical and horizontal) when the manual task was concurrently performed with the extemporaneous speech task compared to the reading task.

Variation in Movement Spectrum

- Participants with PD exhibited a significant increase in the variation of the spectral peak from single- to dual-task condition, $p=0.01$.

Conclusion

These data suggest that the degree of dual-task interference experienced by individuals with PD may be influenced by the demands of the speech task. Individuals with PD exhibited greater bidirectional dual-task interference for the extemporaneous speech task that required generative language.

References

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jawhitf@bgsu.edu