Pause distribution in parkinsonian speech

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INTRODUCTION

A pause is defined as a silent interval or temporary cessation in speech that results result from motoric, prosodic, linguistic, and / or cognitive processes. As such, pause plays a critical role in examining respiration, articulation, prosody, and fluency in clinical populations.

Previous work has used a number of different criteria for measuring pause. Past studies have defined pause as a silent interval in speech lasting at least 10 milliseconds (Skodda & Schlegel, 2008), at least 50 milliseconds (Goberman, Coelho, & Robb, 2005), or at least 200 milliseconds (Bunton & Keintz, 2008).

Relative to pause in Parkinson disease (PD), various studies have found different results. For example, previous literature has shown that individuals with PD typically exhibit longer pause durations than control speakers (Goberman et al., 2005; Goberman & Elmer 2005; Quek et al., 2002). Other studies have examined inspiration and pause independently, and have found shorter pause durations in individuals with PD compared to controls (Huber et al., 2012).

The purpose of the current study was to examine the frequency and duration of silent intervals in connected speech and compare the distribution of these pauses in participants with and without PD.

METHODS

Participants and Protocol: Habitual reading samples (The Caterpillar Passage; Patel et al., 2013) from 10 individuals with idiopathic PD (5 males, 5 females; *Mean Age* = 68.7 yrs., *Age Range:* 60-77) and 10 older control speakers (5 males, 5 females; *Mean Age* = 68.4 yrs., *Age Range:* 64-76) were recorded on to a portable digital audio recorder using a table-top microphone.

Acoustic analysis: Acoustic Analysis was completed using PRAAT (Boersma & Weenink, 2015). Silent intervals longer than 15 ms in duration were identified and labeled using a spectrographic and waveform display. Breaths that were perceptually audible, and thus visually identifiable on the spectrographic and waveform display, were also identified as pause.

Pause durations categories: Following extraction of all silent intervals, the frequency of pause categories was examined based on the following bins:

1. silent intervals less than 50 ms,
2. silent intervals between 50 and 150 ms,
3. silent intervals between 150 and 250 ms, and
4. silent intervals greater than 250 ms.

Gaussian mixture model analysis: The distribution of pause durations was examined for each participant. Because visual inspection revealed that all distributions were negatively skewed, the pause duration values were log transformed. As the log distribution of pause durations yielded bimodal distributions, the means of the first and second modes were identified using a Gaussian mixture model in MATLAB. This function uses an Expectation-Maximization algorithm to estimate parameters of a Gaussian distribution with an expected number of components (modes), similar to the approach described by Rosen et al. (2010). Using a custom script, the means of the first and second mode of the bimodal logarithmic pause distribution were calculated for each participant.

The mean of the first mode corresponded to short pause durations, around 1.7 log ms or 50 ms (i.e., short pauses), and mean of the second mode corresponded to longer pause durations, around 2.6 log ms or 400 ms (i.e., long pauses).

Statistics: A multivariate analysis of variance (MANOVA) using the four pause duration categories as the dependent variables and group as the independent variable was completed. A second MANOVA was completed to examine differences between the average duration of Mode 1 pauses (i.e., short pauses) and Mode 2 pauses (i.e., long pauses) between groups.

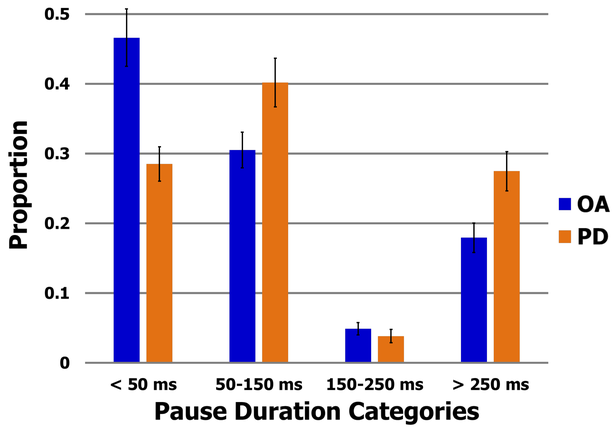

Figure 1. Distribution of pause duration categories measured from the connected speech of individuals with Parkinson disease (PD; orange) and older adult controls (OA; blue).

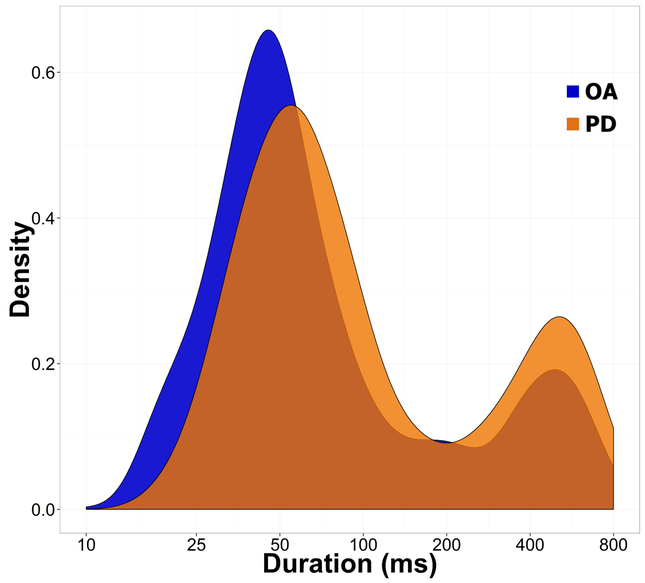

Figure 2. Log distribution of pause duration showing the grand mean of the short pause (Mode 1) and long pause (Mode 2) durations for individuals with Parkinson disease (PD; orange) and older adult controls (OA; blue).

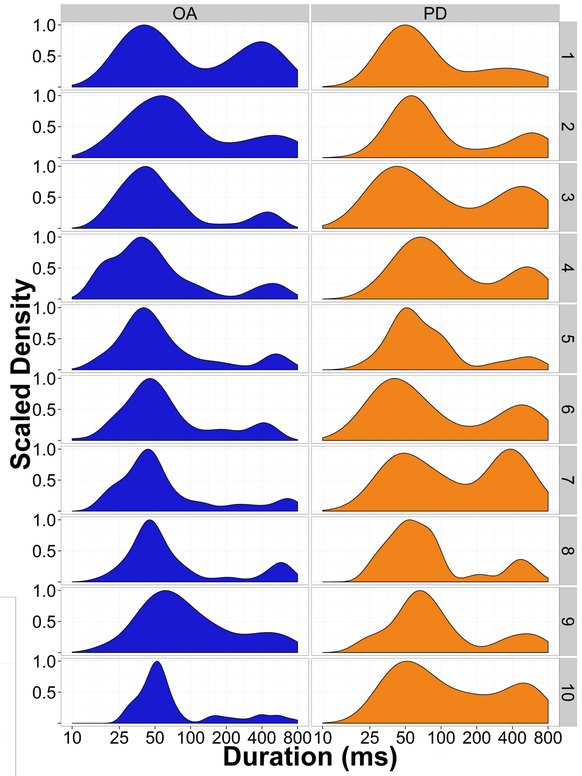

Figure 3. Individual log distributions of pause duration for participants with Parkinson disease group (PD; left panes) and older adult controls (OA; right panes)

RESULTS

Descriptive data:
The average number of pauses identified across all individuals was 104 (*SD*=17.8; *Range:* 60-135).

- There were no differences between the PD group and OA control group in total speaking duration, number of syllables produced, number of pauses, or speech rate, $p>0.05$ for all comparisons.

Pause durations categories:
There was a significant difference between groups for the frequency of pauses in the following categories:

- PD group exhibited fewer pauses that were less than 50 ms in duration compared to the control group, $p<0.001$.
  - PD Group: *M*=27.6, *SE*=2.40
  - OA Group: *M*=51.4, *SE*=5.24
- PD group exhibited more pauses that were greater than 250 ms in duration compared to the control group, $p=0.038$.
  - PD Group: *M*=25.8, *SE*=1.76
  - OA Group: *M*=19.6, *SE*=2.14

Gaussian mixture model analysis of logarithmic pause durations:
Relative to the goodness of fit of the Gaussian mixture models, comparison of the observed values to the predicted values suggested good fits for all participants (*RMS Range:* 0.3-3.5%).

MANOVA results revealed a significant main effect of group for the first mode (i.e., short pauses), $F(1,18)=7.38$; $p=0.014$, but not for the second mode (i.e., long pauses), $p>0.05$.

- For Mode 1, the PD group exhibited longer silent intervals than OA controls.
  - Short pauses in the PD group were on average 55.26 ms;
    - PD Group: *M*=1.66 log ms, *SE*=0.02
  - Short pauses in the OA group were on average 46.16 ms.
    - OA Group: *M*=1.74 log ms, *SE*=0.02
- For Mode 2, there were no differences between groups
  - Long pauses were on average 2.59 log ms, or 410.91 ms across all participants.
    - PD Group: *M* =2.59 log ms, *SE*=0.06
    - OA Group: *M* =2.59 log ms, *SE*=0.05

CONCLUSIONS

In the current study, the PD group exhibited significantly fewer pauses that were less than 50 ms when compared to control speakers. In addition, these short silent intervals (i.e., Mode 1 pauses) were significantly longer for participants with PD than control speakers. Conversely, participants with PD exhibited significantly more pauses that were greater than 250 ms when compared to controls. However, there were no between-group differences in the duration of these longer silent intervals (i.e., Mode 2 pauses).

The lengthening of short silent intervals and increased frequency of longer pauses may result from a number of factors. It is possible that the prolonged short intervals and greater frequency of long pauses may result from disordered speech motor timing. A slight delay in the phoneme-to-phoneme transition, stuttering-like blocks, or akinesia may explain these findings. Other work has hypothesized that individuals with PD may exhibit a greater proportion of pause to compensate for speech motor deficits (Goberman & Elmer, 2005). Future work should determine if these abnormalities in the pause distributions result from a compensatory use of clear speech strategies during habitual speech production or a more general deficit in speech motor timing.

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