COMPARING SPEECH TO FINE AND GROSS MOTOR SKILLS IN PARKINSON'S PATIENTS

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1 Introduction

Parkinson's Disease (PD) is a neurodegenerative disorder resulting from damage to the dopaminergic neurons integral to motor control. This leads to impaired motor control throughout the body, including in locomotion, manual motor control, and speech articulation. One characteristic symptom of PD is bradykinesia which can manifest in terms of slowness in actions as well as difficulties with the initiation of movements. Previous studies have found relationships between bradykinesia in the upper extremities and acoustic speech variables [1]. This works extends upon previous studies of PD by considering the presentation of bradykinesia jointly across multiple task modalities. This analysis focuses on how the initiation patterns of movements in PD patients can differ from that of stable movement portions.

2 Method

2.1 Dataset and Processing

The analysis is conducted using data from the mPower study [2]. The mPower study is an observational study containing crowdsourced data including patients who self-identified as having been diagnosed with PD.

The study includes data from three tasks that each correspond to a different motor task: a sustained vowel phonation task (speech articulation), a finger tapping task (manual motor), and a walking task (locomotor). We extract acoustic features known to such as fundamental frequency (F0), formants, shimmer, jitter, and HNR. [3] For finger tapping, we adapt measures of tapping and walking consistency from previous work. [4, 5]. In order to study the differences between initiation patterns of movements, we extract features on both the onset and medial portions of each task. The onset of each task refers to the initial portion, (first 5% of task duration for vowel phonation and first 10% of task duration for finger tapping and walking) and the medial portion refers to the period between the 25% to 75% of each task. Features are then all z-score normalized within each speaker.

2.2 Analysis Methods

We perform clustering on the basis of relevant participant data such as professional diagnosis history and task window (onsets or medials) to examine how participants vary among the different features. We then use multidimensional scaling (MDS) for dimensionality reduction and visualization of the cluster centroids across modalities [6]. With MDS, the relative distances between points in the lower dimensional plot is indicative of the relative similarity such that closer points in space are more similar to each other than those further away from each other.

We also fit a logistic regression model to predict diagnosis label given extracted features from all task modalities in the onset. We report statistically significant features that are predictive of PD.

Table 1: Summary of tasks and corresponding extracted features

Task Name	Extracted Features
Sustained vowel phonation	F0, F1, F2 (mean, variance) Shimmer Jitter Harmonics-to-Noise Ratio (HNR)
Finger tapping	Temporal Consistency (timing regularity of tapping) Spatial Consistency (spatial regularity of tapping) Tapping Accuracy (percentage of targets hit) Tapping Rate (taps per second)
Walking	Outbound acceleration (mean, variance) Outbound rotation rate (mean, variance) Resting acceleration (mean, variance) Resting rotation rate (mean, variance)

3 Results

We find that the cluster centroids are maximally differentiated in acoustic features by both task window and PD diagnosis status in Figure 1(a). However, for finger tapping, we find that the groups are well separated by PD status, but only those without a diagnosis have a separation between onset and medial portions 1(b). In the case of walking, we find that the clusters remain maximally differentiated by diagnosis status but the task window between medial and onset portions does not separate the clusters well 1(c).

In our logistic regression, we find that higher mean F0 ($p < 0.01$) and shimmer ($p < 2e^{-16}$) are positively correlated with PD whereas high HNR ($p < 2e^{-16}$) is correlated with non-PD diagnoses. In terms of tapping, we find that lower spatial consistency ($p < 0.001$) and tapping rate ($p < 2e^{-16}$) are also correlated with PD. In walking, lower mean acceleration ($p < 0.001$) and rotation rates ($p < 2e^{-16}$) in the walking task correlate with PD.

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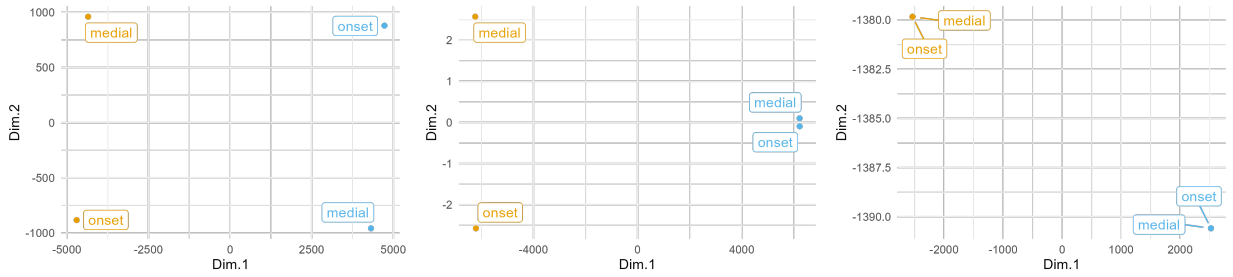

(a) (b) (c)

Figure 1: Multidimensional scaling (MDS) plots for (a) acoustic features, (b) tapping features, and (c) walking features respectively, showing similarity in features between diagnosis condition (PD diagnosis in blue, no diagnosis in orange) and onset vs. medial

4 Discussion

Looking at the MDS plots, we find mixed results with respect to the degree of which bradykinesia may manifest in the different tasks. In the acoustics, the strong separation of each cluster by diagnosis and task window suggests that PD has distinct effects on the initiation of vowel phonation beyond regular differences between those inherent to onset and medial portions. In the finger tapping task, the clusters exhibit high separation between the onset and medial window only within the non-diagnosed condition. This suggests that PD may cause these two parts of the task window to converge in terms of their features. In the walking tasks, we see little separation between onsets and medials in each condition but high separation based on diagnosis. This suggests that PD itself has characteristic effects across the duration of walking.

In the logistic regression model, we find that higher mean F0 and shimmer are correlated with PD. This is consistent with previous PD literature on the acoustics of PD speech [7]. We also find that high HNR values are correlated with non-PD diagnoses which is sensible as PD patients with dysphonia should have low HNR. Lower spatial consistency and lower tapping rate were also correlated with PD. This is expected given the effects of bradykinesia includes slowness of movements in general. Lower mean acceleration and rotation rates were found to correlate with PD. These deficits are consistent with previous work that suggests that slowness in turning arises from a compensatory strategy to prevent postural instability [8]. With regards to posture, previous work suggests that there exists a unified posture control system for both motor and fine-motor tasks [9, 10]. We propose that the motor impairments we observe across disparate physiological subsystems could be related to how PD may attack this system.

5 Conclusions

We demonstrate that in a variety of movement tasks, the initiation patterns of the task can show demonstrably different characteristics than that of the sustained portion, particularly in those with PD and in their speech. These differences in initiation patterns may be partially explained by bradykinesia. For future research, these initiation patterns are key to achieving a holistic understanding of PD.

Acknowledgements

This work was completed with funding from an NSERC Discovery grant to the last author.

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