Effect of Hearing Loss on Prosodic Intervention in Parkinson's Speech

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ABSTRACT

This study tests the effect of hearing loss on prosody in people diagnosed with Parkinson's disease (PD). Speech therapy for hypophonia in this population involves cueing speakers to increase their speech loudness. A complete audiological evaluation was completed on all participants that included pure tone hearing range, speech discrimination, comfortable loudness levels and dynamic range. Audiological testing was used to group the participants into two groups: mild to moderate and severe hearing loss. They were then asked to read a phonetically balanced sentence at four levels of self-perceived loudness (50%, 100% 200% and 400%). Changes in intensity and pitch range were compared for the two groups. The results indicate a negative impact of low dynamic hearing range on the participants' perceptual scale for loudness which resulted in lower intensity and pitch range. Impact of these findings on current speech therapy is also discussed.

Keywords: Parkinson's disorder, hearing loss, speech discrimination threshold, loudness, and pitch.

1. INTRODUCTION

Parkinson's disease (PD) is a neurological disorder of the basal ganglia, which according to Canter [1] is characterized by disturbances in muscular control including tremors, slowed movements, and muscle rigidity. Typical speech characteristics of PD include inappropriate silences, monopitch, monoloudness, short rushes of speech, slightly fast rate of speech, harsh or breathy voice, and imprecise consonants, due to the reduced range of movement of the speech articulators (Darly et al., 1969) [2]. Hypophonia or reduced speech loudness is a common indication of speech involvement in individuals with PD (Dykstra, 2012) [3] and also the major symptom that is remediated in speech therapy [4, 5]. Along with disruption to the speech system, researchers have established that auditory system dysfunction is a common nonmotor feature of patients with PD (Jafari, Kolb, & Mohajerani, 2020) [6]. Yet, there has been little attention in clinical practice to the impact of hearing impairment on speech perception, social communication, and quality of life [6].

Ho et al. (2000) [7] reported that individuals with hypophonia can improve their loudness when provided with external cues. Clark *et al.* (2014) [8] examined the loudness perception of individuals with hypophonia compared to a healthy control group by administering three loudness perception tasks. One task involved participants producing a sentence at normal level, then two times and four times quieter and louder. The participants with PD demonstrated a more restrictive loudness range and lower speech intensity compared to the control group. These results suggest that hypophonia may be due to a deficit in speech loudness perception. Yet, this study did not incorporate audiometric evaluation, so it is challenging to say if the restricted loudness range is due to speech perception deficits or hearing performance. De Keyser *et al*., (2016) [9] studying the relationship between speech production and speech loudness perception in individuals with mild PD, found no significant difference between PD and healthy control, however, their PD participants were better able to meet their target intensity when they were provided with cues on intensity levels.

In this study, we test the effect of hearing loss on participants' self-perception of loudness and its effect on speech prosody. In this preliminary publication we test only the aspect of pitch range when participants produce speech at different levels of loudness with the inclusion of hearing evaluation to better understand the influence of hearing.

2. METHOD

2.1. Participants

The participants analyzed in this study include four female individuals with PD. Participants were recruited from the University of Toledo Speech-Language Clinic where they received speech diagnosis and PD therapy.

2.2. Audiological evaluation

Audiometric evaluations were completed in a sound treated room with a calibrated diagnostic audiometer. Testing revealed the presence of sensorineural hearing loss in all subjects. Only one subject utilized hearing aids and those instruments provided inadequate access to the full range of speech sounds.

Table 2: Participant demographics.

Participant	Age (years)	Months since diagnosis
2PD	70	12
5PD	92	96
6PD	88	132
7PD	64	144

2.3. Speech paradigm

Speech data was extracted from the speech diagnosis protocol. Here the participants were asked to read the utterance “Kick the ball straight and follow through,” at different levels of self-perceived loudness, similar to the protocol employed by Clark [5]. Participants were told to read the utterance at their most comfortable loudness and habitual pitch. They were then instructed to read it four more times. Their most comfortable loudness was referred to as 100%. They then had to read the same sentence at 200%, 400% and 50% loudness. All participants produced the utterances in the same order. It is expected that the reading at 50% would be influenced by the 200% and 400% productions, so they were asked to produce the 100% again one time before reading the utterances at half loudness. Each of these levels were produced five times. At no time were the participants provided the decibel rating of their loudness.

2.4. Analyses

For this publication, participants were grouped into mild-moderate hearing impairment (MHI) for hearing thresholds between 25-55 dBHL and severe hearing impairment (SHI) for thresholds >56 dBHL. Mean speech intensity values were calculated over the entire utterance separately for all individuals and levels of loudness. Similarly, pitch range values were calculated separately for all individuals and levels of loudness. We believe that pitch range gives us a more comprehensive understanding of the participants' pitch profile.

3. RESULTS

3.1. Audiological report

Audiometric findings are summarized in Table 2. Two subjects had MHI with normal word discrimination ability in optimal listening conditions. Two subjects had SHI with fair word discrimination ability in optimal listening conditions. All demonstrated a reduced dynamic listening range: the greater the loss, the more diminished the range for these subjects.

Table 2: Audiometric report for all speakers.

Subject	Ear	Hearing Range	SRT	Speech Discrimination	MCL	UCL	Dynamic Range (UCL-SRT)
2PD	Right	Normal to mild loss	10	92%@50 dBHL	55	85	75
	Left		10	100%@50 dBHL	60	85	75
7PD	Right	Normal to moderate loss	20	100%@50 dBHL	55	80	60
	Left		15	100%@50 dBHL	50	80	65
5PD	Right	Mild to profound loss	60	62%@75 dBHL	70	95	35
	Left		60	84%@75 dBHL	75	95	35
	Aided	Aided	35	86%@50 dBHL	50	70	35
6PD	Right	Moderate to profound loss	75	68%@85dBHL	80	100	25
	Left		70	64%@85 dBHL	80	100	25

3.2. Intensity

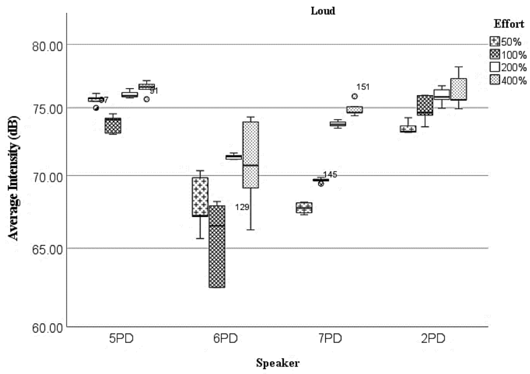

Figure 1: Boxplots of average intensity for speakers separated by loudness level. Speakers 5PD, 6PD SHI, speakers 7PD, 2PD MHI

Figure 1 displays the average intensity values calculated over the entire utterance separated by each speaker for the different levels of self-perceived loudness. Speaker 6PD had the lowest overall intensity and the greatest difference between the different levels of loudness; however, she also demonstrated a lot of variation across the individual repetitions. Looking at Table 3, we see that this participant had a 14dB increase from 100% to 200% but approximately 2dB decrease from 200% to 400%. In contrast 5PD, who is grouped together with 6PD on hearing response had limited change in intensity across the loudness levels, but she also had lesser sentence to sentence variations. Referring to Table 3 again, we see that 5PD has intensity values congruent with the MHI participants but the difference between the levels is most evident only between 100% and 200% which was a difference of 2dB. She increased her intensity by only 0.5 dB when she doubled her loudness from 200%. Speakers with mild to moderate hearing impairment were able to clearly distinguish each level of loudness with lesser variation. For every level of loudness, they exhibited a difference of 1 or 2dB amplitude, depending on the speaker. Generally, we note that PD participants perception of doubling loudness was on average 1.5 to 2dB.

Table 3: Average intensity and pitch range values for all speakers for different loudness levels and HI.

Hearing	Speaker	50% Loudness		100 % Loudness		200% Loudness		400% Loudness	
		Intensity (SE)	Pitch Range (SE)	Intensity (SE)	Pitch Range (SE)	Intensity (SE)	Pitch Range (SE)	Intensity (SE)	Pitch Range (SE)
Severe	5PD	76 (.18)	167 (11)	73.8 (.31)	135.7 (15.5)	76 (.1)	168 (11)	76.5 (.24)	167 (8.25)
	6PD	68 (.89)	81.8 (9.2)	63.9 (2.5)	119 (14)	78.6 (.85)	145.9 (14.5)	76.9 (1.5)	154 (20.7)
Moderate -Mild	7PD	67.7 (.17)	84.5 (5.8)	69.7 (.07)	130 (4.5)	73.8 (.11)	178 (6.6)	74.9 (.26)	206.8 (1.8)
	2PD	73.5 (.21)	170.9 (10.8)	74.9 (.46)	267 (6.5)	75 (.30)	317.8 (14.3)	76 (.61)	303.6 (12.8)

3.3. Prosody

Pitch range was calculated for all speakers separately for the different levels of loudness due to individual variation in symptoms of PD and hearing loss. For all speakers pitch increased as loudness increased with the exception of 5PD at 50% level of loudness. However, it should be noted that this level was produced with higher intensity than her 100%. The correlation of loudness and pitch range was positive and significant for all speakers. However, the correlation was lesser in the SHI group (r (77) = .67, p < .001) when compared to the MHI group (r (77) = .83, p < .001).

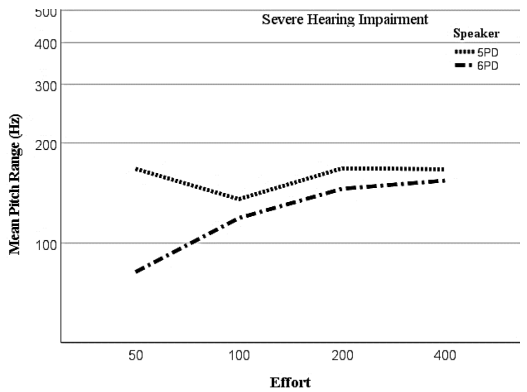

Figure 2: Line graphs of average pitch range for SHI speakers separated by loudness level.

Figure 2 plots line graphs for the two SHI participants separately for the different levels of loudness. We see that pitch range for these two speakers are relatively narrow falling between 68 to 167 Hz. Note that 50% for 5PD is higher but her intensity measure for this level is also higher than her habitual production (100%). Her pitch range decrease from 100% to 50% is approximately 30 Hz, however, between 50%, 200% and 400% her pitch range does not change similar to her intensity values.

Speaker 6PD exhibited on average a change in pitch range equivalent to 30Hz through the levels of 50%, 100% and 200%. From 200% to 400% she had decreased her intensity by approximately 1.5 dB, but she increased her pitch range by approximately 10 Hz. In general, this speaker was not able to accurately scale her intensity, but she was better with her pitch modulation.

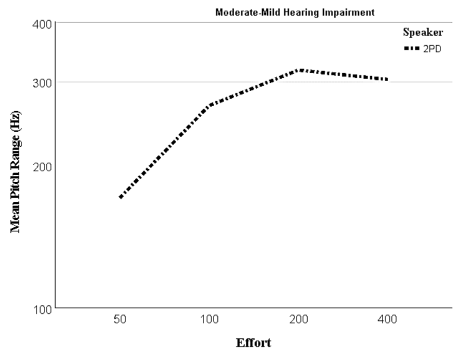

Figure 4a: Line graphs of average pitch range for MHI speaker 2PD separated by loudness level.

Figures 4a plots the pitch range for 2PD. The pitch range for this speaker was approximately 148 Hz with approximately 45 Hz increase for every perceptual doubling of loudness. We see a similar large pitch range (122.5 Hz) in Speaker 7PD as seen in Figure 4b. For every perceptual increase in loudness this speaker also had approximately 45 Hz increase in pitch range.

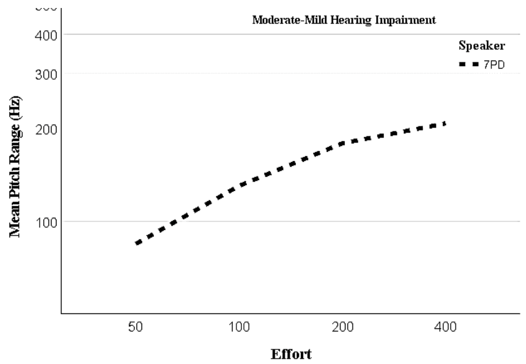

Figure 4b: Line graphs of average pitch range for MHI speaker 7PD separated by loudness level.

4. CONCLUSION

Our results indicate negative interaction between hearing loss and pitch range depending on the speech dynamic range in people diagnosed with Parkinson's disease. Pitch range was reduced in persons classified as SHI when compared to those classified as MHI. However, pitch range significantly increased with greater loudness.

Except for Speaker 6PD, all speakers had a gradual increase in intensity as the perceived levels of loudness were doubled. 6PD's intensity change was erratic increasing by 14dB difference between 100% to 200% but a decreasing from 200% to 400%. This indicates that she was not able to achieve an accurate scaling of her perceptual loudness. Interestingly, she has the most impaired loudness perception, tolerating only 25 dBHL (dynamic range), which may certainly impact self-monitoring and control. Speaker 5PD, also classified as SHI, on the other hand was not able to perceive a halving of loudness from 100% to 50%. Similarly, she was only able to increase loudness by half a decibel when asked to double her intensity from 200%. She is the only subject with hearing aids, but due to their inadequate support, may negatively influence her responses. Further, the devices themselves may also impact her loudness perception in the way they process sound input.

On the other hand, the speakers classified as MHI were able to demonstrate a gradual increase in their perceptual scale of loudness though it varied from one speaker to the other. On average, a 1.5 to 2dB difference in amplitude was observed for every doubling on the perceptual scale. This intensity change over the scale also showed a steadying increase in pitch range. Both also demonstrated better loudness tolerance with wider dynamic listening ranges.

5. DISCUSSION

Within our small subset of speakers, we see several individual variations in intensity and pitch range related to their difference in Parkinson's disease symptoms and hearing loss. However, we see a compromise in their perceptual scale of loudness based on their speech dynamic range. Speakers with better hearing and dynamic range were classified as mild to moderate speech while speakers with more severe hearing loss and smaller speech dynamic range were classified as severe in this study. This classification for this preliminary study held true when comparing their performance on their self-perceived loudness scale.

All participants were able to perform the task to some degree of accuracy, but it is clear that speech therapy for the remediation of hypophonia needs to be more granular to address the inherent prosodic changes and the interaction of prosody. Further, these results support findings reported by Jafari et al. (2020) with regards to the need for far more attention in clinical work to a wide range of aspects of the impaired auditory system [6]. More comprehensive audiological evaluation is warranted. For without it, it is unclear how patients with hearing impairments that are largely untreated can benefit from intervention. Further, without audiological information, it is challenging to determine if benefits from intervention are simply due to adequate auditory access and dynamic listening range more so than the treatment itself.

7. REFERENCES

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