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OROFACIAL SOMATOSENSATION IN PEOPLE WITH PARKINSON'S DISEASE

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ABSTRACT

Throughout every stage of life, communication remains a vital component to humans' quality of life. However, problems in communication can occur which may require remediation services to improve communication skills. Typical speech-language therapy occurs using techniques that rely upon adequate somatosensory channels for feedback. This study aims to quantify changes in orofacial somatosensation in people with Parkinson's disease. We hypothesize people with Parkinson's disease may experience changes in orofacial somatosensation, impacting speech and swallowing, and leading to a decrease in overall quality of life. To assess this hypothesis, four adults (two males and two females) diagnosed with Parkinson's disease participated in this study. Using Von Frey Hair monofilaments and two-point discrimination discs, participants' orofacial somatosensory thresholds were tested in four regions, the right and left portion of their bottom lip and the right and left portion of their lateral tongue tip. Participants demonstrated increased threshold estimates (worse sensation) than previously published data for healthy, young controls. This study adds valuable information for future researchers regarding the impact of Parkinson's disease on orofacial somatosensation. Additional research in this area could allow speech pathologists to tailor services for individuals with Parkinson's disease by assessing orofacial somatosensation and adjusting therapy stimuli based on the client's somatosensory profile.

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Chapter 1

Introduction

Since humans are very social creatures, we rely heavily on communication with each other for information transfer, social closeness, social etiquette, and communicating needs and wants (Light, 2017, Lecture). One way to achieve communication is using oral communication with language and speech. Language is a code we use to organize messages, and speech is the production of acoustic targets to express the language (Wilkinson, 2018, Lecture).

Oral communication is a cycle: we must hear what our communication partner says, and then we must understand and interpret their message. After understanding the message, we create an internal response and express it to our partner through speech ("Communication in the Real World, 2016). Humans of all life stages use some type of communication and may experience problems. Late adulthood is a common life stage where communication breakdowns can occur due to age-related changes in hearing or disease and disorder. The aging population may seek out speech-language pathology services to improve communicative abilities.

Aging adults can have hearing loss resulting in misunderstood messages and errors in their own speech ("Effects of Hearing," n.d.). They also experience decreased reaction speed and deficits in short-term learning (Ryan, Giles, Bartolucci, & Henwood, 1986). In speech production, dysfluencies, slower rate of speech, and decreased loudness are common changes in aging adults (Ryan et al., 1986). People with Parkinson's disease can experience these changes and more as consequences from the disease.

Parkinson's disease is a neurodegenerative disease from the reduction of dopamine and the creation of lewy bodies in an individual's brain (DeMaagd & Philip, 2015). These brain changes cause symptoms such as slower movements, rigid muscles, and a resting tremor (Sveinbjornsdottir, 2016). These brain changes can also affect the senses: taste, touch, smell, hearing, and vision.

The focus of this study is to identify the changes that may occur in orofacial somatosensation in people with Parkinson's disease. This focus allows us to gain a better understanding of this population's orofacial somatosensation in relation with speech functions. By understanding the holistic reasoning behind speech issues, services may be better tailored and more effective for these clients.

Chapter 2

Literature Review

Humans rely on communication to fulfill the needs of information transfer, social closeness, social etiquette, and communicating needs and wants (Light, 2017, Lecture). From early infancy to late elderly stages, communication remains an important aspect of people's lives. Communication can use speech, but it is not the only means to convey messages as it also involves gesturing, body language, and facial expressions (Wilkinson, 2018, Lecture). Language is the code we use to organize sounds, signs, or written symbols to systematically create and understand messages (Wilkinson, 2018, Lecture).

Oral communication is comprised of several components: hearing, receptive and expressive language, and speech, as shown in various communication models ("Communication in the Real World, 2016). In order to use this type of communication, we must be able to hear what our communication partner says. We then take the message we heard and aim to understand our communication partner's message. This is known as reception. After understanding what they said, we formulate a response, known as expression, and convey it back to our communication partner through the medium of speech ("Communication in the Real World, 2016).

Problems in communication may arise at any of the developmental stages. Late adulthood tends to be a common period where speech pathology services are needed. It is common for typically-aging adults to have hearing loss in either or both ears. Hearing loss usually results in loss of ability to hear high frequency sounds, like "s" and "f," resulting in not hearing full messages, misinterpreting messages, and producing incorrect messages themselves. Hearing loss may also lead to social isolation from difficulty in forming friendships and other bonds ("Effects of Hearing," n.d.). In receptive language, typically aging adults can exhibit decreased speed of processing and reaction to information, along with issues in new learning (Ryan, Giles, Bartolucci, & Henwood, 1986). In their expressive language, dysfluencies of speech are more common. Aging adults may also experience a reduction in rate and loudness of their speech (Ryan et al., 1986). Geriatric communication problems can also be exacerbated by degenerative diseases, such as Parkinson's disease. Aging individuals with Parkinson's disease may have all the difficulties outlined above as well as additional difficulties.

Parkinson's disease is the second most common neurodegenerative disease in aging adults, with prevalence increasing with age (Sveinbjornsdottir, 2016). According to DeMaagd & Philip's (2015) overview of Parkinson's disease, it can be described as a reduction in dopamine that lessens motor functioning. This disease affects brain structures like the basal ganglia and the vagus and glossopharyngeal nerves. There is also an abnormal growth of lewy bodies in the brain's neurons. DeMaagd & Philip (2015) say lewy bodies are "described as intracellular cytoplasmic aggregates composed of proteins, lipids, and other materials." These lewy bodies are associated with the dementia of Parkinson's disease. Formations of lewy bodies vary through the different stages of Parkinson's disease (DeMaaggd & Philip, 2015).

Braak et. al (2003) broke down Parkinson's disease into six disease stages. Stages one and two are when lewy bodies are only in the medulla oblongata and the olfactory bulb. Symptoms are very subtle, almost unnoticeable, during these stages. In stages three and four, the substantia nigra and nuclei of the midbrain and forebrain become affected. The final stages, stages five and six, are when the symptoms became severe and more inhibiting (as cited in

Sveinbjornsdottir, 2016). According to Chung et al. (2001), by the time identifying symptoms appear in stages three and four, 80% of dopamine cells are lost (as cited in Sveinbjornsdottir, 2016). These hallmark symptoms may include slower initiation of movement (bradykinesia) with rigid muscles or a resting tremor. Parkinson's disease also begins with unilateral symptoms, and then later develops contralateral symptoms (Sveinbjornsdottir, 2016). Clinical symptoms that occur include a forward-bent body, shuffling gait, lack of facial expression, smaller handwriting, balance issues, and freezing movements (Sveinbjornsdottir, 2016). The changes in the brain also affect speech in people with Parkinson's disease. Regarding speech functions, people with Parkinson's disease can be characterized as having monotone, dysfluent speech. These specific speech changes negatively affect communication (Miller, Noble, Jones, & Burn, 2006).

People with Parkinson's disease also experience reductions in the five senses: smell, taste, vision, hearing, and somatosensation (Sveinbjornsdottir, 2016). People with Parkinson's disease can experience a reduction in sniffing ability. They tend to use less force when sniffing and had lower performance on olfactory tests (Sobel et al., 2001). This reduction could be a result from damage to the olfactory system from Parkinson's disease or possible sniffing impairments. Sniffing transports smells to the olfactory receptors, affects neural activity, and is used in identifying different smells. Reduction in olfaction, as found in people with Parkinson's disease, may reduce quality of life since individuals may not smell familiar scents they enjoyed before reductions occurred (Sobel et al., 2001). People with Parkinson's disease also experience changes in taste. By examining gustatory receptor cells, researchers have studied the changes in taste (Heckmann, Heckmann, Lang, & Hummel, 2003). The glossopharyngeal nerve is one of the nerves that carries taste cells' information. Since this nerve is affected by Parkinson's disease, people under this diagnosis can be expected to have affected gustation. Gustatory dysfunction in

Parkinson's disease could also be a result from taking the drug, levodopa (Heckmann et al., 2003). Like olfaction, gustatory dysfunction can decrease quality of life where individuals can no longer enjoy the tastes of their favorite foods. Vision changes can also occur with Parkinson's disease. One type of visual change is the development of visual hallucinations and delirium due to advanced dementia, infections, and dopaminergic drugs. The dopamine loss in Parkinson's disease also results in retinal deficiency that affects their performance on Visual Evoked Potentials (Bodis-Wollner, 1990). Bodis-Wollner's (1990) findings imply that dopamine may play a role in vision functions. Vision impairments affect quality of life for cognitive tasks, tasks for daily living, and work and social life. Another sense that is affected by Parkinson's disease is hearing. Although typically aging adults experience hearing loss, studies have found that people with Parkinson's disease are more affected by hearing loss, especially in the higher frequency sounds (Vitale et al., 2012). There is still further research required for how hearing is affected by the dopamine loss. However, just like typically-aging adults, adults with Parkinson's disease will experience a decrease in quality of life and communication because of hearing problems (Vitale et al., 2012).

Finally, people with Parkinson's disease can experience changes in somatosensation in different areas of the body. One study found pressure sensitivity is higher in the upper extremities in people with Parkinson's disease. Meaning the upper half of the body has better sensitivity than the lower half (Doty et al., 2014). Another study found a negative correlation between the progression of Parkinson's disease and the sensitivity of the soles of feet. As the disease progressed, the sensitivity decreased which could be a contributing factor to impaired balance in people with Parkinson's disease (Prätorius, Kimmeskamp, & Milani, 2003).

Changes in voice, such as softer vocal intensity and onset errors are distinctive hallmarks of Parkinson's disease. These voice changes may be related to the somatosensory changes like reduced respiratory driving pressure and decreased vocal adduction from the degeneration (Hammer & Barlow, 2009). While previous literature has shown changes in general body somatosensation, this study will specifically focus on orofacial somatosensation. The orofacial region consists of the tongue, upper and lower lips, and the jaw (Solomon, Robin, & Luschei, 2000). These structures are crucial in speech production; therefore, this study's focus is to understand how deficits in somatosensation in this region affects speech.

One study by Schneider, Diamond, & Markham (1986) aimed to assess orofacial somatosensation in Parkinson's disease through ten different motor and sensory tests. The Parkinson's disease group made more errors in the tests than the control group. Age also played a factor in performance; the older adults in both groups made more errors than the younger adults of the groups. On eight out of the 10 tasks, the group with Parkinson's disease performed worse than the control group. The jaw proprioception and tactile localization on tongue, gums, and teeth were especially successful in discriminating the oral somatosensation differences between the Parkinson's disease group and the control group (Schneider et al., 1986).

This current study aims to add further literature on orofacial somatosensation in people with Parkinson's disease using the same protocol as a study by Etter, Miller, & Ballard (2017) with healthy, young adults to assess orofacial somatosensation using clinical measures. Understanding the somatosensation of speech functions will allow us to better understand if impairments or deficiencies influence motor skills, thereby affecting people's communications. By continuing to disseminate research, clinicians will be able to treat clients more effectively. Based on previous research, we hypothesize people with Parkinson's disease will have higher orofacial somatosensory threshold estimates (or decreased somatosensation) as compared to the healthy aging control population. Meaning, people with Parkinson’s disease will require higher levels of pressure to their lips and tongues to confirm they are feeling different types of pressure.

Chapter 3

Methods

Participants

Participants for this study were recruited from the greater Centre County, PA area. Four people with Parkinson's disease, two males and two females ages 74 to 82 years, participated in this study. After verbally explaining the consent for research, each participant completed a brief oral assessment of capacity to consent to ensure they understood the purposes and procedures of this study. Additionally, participants self-reported their alertness and eligibility in meeting study criteria in other screening measures before assessment. The participants were volunteers and did not have any prior experience to the assessment measures used. The university's ethic counsel approved this study before recruitment.

A basic case history gave participants the opportunity to self-report on various health questions. Using a scale from 1 to 5 with 5 being the best, all participants reported a 3.5 or higher when asked to rate their health on the day of testing. The questionnaire also addressed smoking history and experience playing a musical instrument. Additionally, there were questions addressing any communication difficulties they might have experienced. The complete health questionnaire is included in Appendix A. These communication questions allowed for a transition into the second screening measure, hearing thresholds. Using an InterAcoustics AD 629 audiometer with earphone inserts, all the participants' hearing thresholds were assessed at 500, 1000, 2000, and 4000 Hz. A picture of the audiometer used can be found in Appendix B. Participants were also asked to identify their typical speech usage based on a 5-point scale provided to them. The speech usage scale can be found in Appendix C.

After the hearing screening and responding to the speech usage scale, a speech sample was gathered. This sample included tasks such as sustained vowels, repetitions of consonant-vowel syllables (ex. "pa"), various automatics such as counting from one to twenty, word and sentence repetitions, reading the Grandfather paragraph out loud, and finally telling a story about a vacation they have taken. The entire speech sample protocol can be found in Appendix D.

Assessment Procedures

Three different somatosensory assessments were performed on the participants who sat upright in a comfortable chair, as they would in a clinical setting. The assessments were completed in one session and took approximately one and a half hours to complete. All participants completed the assessments in the same order; two-point discrimination, detection, and discrimination. The first assessment used a discrimination disc while the second and third assessments used Von Frey Hair monofilaments. Assessments were completed on four regions of the face: right-side of the lower lip, left-side of the lower lip, right-side of the tongue, and left-side of the tongue. The lower lip was assessed at a midway point between the middle of the lip and the oral angle. The tongue was assessed on both lateral edges of the tongue slightly behind the tip. Although the assessment order remained the same, the order of the assessment locations was randomized for every participant.

Participants were instructed to relax their jaw, allowing access to these oral locations. They were also instructed to close their eyes during somatosensory testing. Closing the eyes helped to discourage participants from guessing and predicting on the assessment task. When assessing somatosensation in the tongue, they were asked to slightly stick out their tongue over their relaxed jaw or to insert their tongue between their teeth. They could close their mouth, swallow, lick their lips, and do other variations throughout the assessments to prevent their mouths from drying. They could also take a brief pause and water break. Feedback on correctness of responses was not given to participants during the assessments.

Two-Point Discrimination Threshold Assessment

The two-point discrimination threshold assessment was completed by using a Baseline Discrim-a-gon 2-point discrimination disc placed with pressure at a perpendicular angle to the areas being assessed (Gescheider, 1997; Rosenbek, Wertz, & Darley, 1973). This assessment used the Method of Limits approach. There was no additional control for pressure to allow for simulation of assessment in a clinical setting. The starting stimulus was 8 millimeters (mm), the largest distance between two points of the smaller disc. Another disc with further distances was available if a participant could not identify the initial stimulus in the previous disc. A picture of these discs can be found in Appendix E. The participants were asked to identify when they felt one or two points by holding up the number of fingers that corresponded. When the starting point had two points, the researcher continuously decreased the distance between points by 1 mm until the participant indicated that they felt only one point of pressure. When the starting point was one point, the researcher continuously increased the distance between points by 1 mm until the participant indicated that they felt two points of pressure. There were randomly presented multiple one-point stimuli to deter participants from guessing or deducing a pattern. There were three descending and three ascending trials using this procedure for every oral location. The millimeter at which the participant felt the change in point pressure was recorded as their score.

The average of the six trials was the threshold estimate in millimeters. This process was completed for each of the four areas and took approximately 10 minutes.

Tactile Detection Threshold Assessment

The tactile detection assessment used Von Frey Hair monofilaments ranging from 0.008g to 300g; however, this study had 15g as the ceiling for testing. The target forces of the monofilaments were 0.008, 0.02, 0.04, 0.07, 0.16, 0.4, 0.6, 1.0, 2.0, 4.0, 6.0, 8.0, 10.0, and 15.0g. A picture of the Von Frey Hair monofilaments can be found in Appendix F. The monofilaments were perpendicularly pressed into the test areas until the monofilament bent. The starting stimulus target force for this population was 1.0g. The researcher verbally expressed the first and second trial; only one of the trials had the stimulus. The presented stimulus was randomized for every set of trials. The participants were instructed to indicate which of the trials they felt the pressure by holding up one or two fingers for trial one or trial two. Following their response, the next set of trials began. If the participant indicated three correct consecutive detections, the researcher would decrease the target force to the next lower monofilament for the next set. If the participant made one incorrect detection, or could not detect any pressure in either trial, the researcher increased the target force to the next monofilament. Assessment continued until the participant crossed over a target force five times. All four locations were tested to determine each area's threshold. The order of locations was randomized for each participant. There was no predetermined minimum or maximum number of trials for this assessment. This assessment took approximately 10-30 minutes to complete.

Tactile Discrimination Threshold Assessment

The final assessment also used the Von Frey hair monofilaments. The threshold determined in the detection assessment was used to determine the starting stimulus point for discrimination assessment. Three increments of monofilaments above the detection threshold was the starting stimulus for the discrimination assessment. Assessment procedures for discrimination threshold estimates were similar to detection threshold estimates. However, instead of feeling a point of pressure in only one of the trials, the participants were instructed that they would feel pressure in both trials. The participants were asked to indicate which trial they felt contained the “harder” or “stronger” pressure. The same stopping procedures were used in this testing paradigm as the detection threshold testing. Discrimination testing took approximately 10-30 minutes to complete.

Chapter 4

Results

Four adults with Parkinson's disease participated in this study. The demographics of the four participants are shown in Table 1. Participants self-reported age, sex, occupation, general health on day of assessments from a scale of 1 to 5, smoking history, and if they ever played a musical instrument. To maintain confidentiality, all participant data has been de-identified.

Table 1. Participant Demographics

Subject Code	Birthdate	Age	Sex	Occupation	Health	Smoker	Musical	Type
PD01	12/9/1934	82	Female	Housewife, Retired	4	No	No	n/a
PD02	7/6/1943	74	Female	Retired Nurse, Seasonal Business Owner	4	No	Yes	Piano and Saxophone
PD03	7/8/1935	81	Male	Retired Engineer	4	No	No	n/a
PD04	5/10/1937	80	Male	Retired	4	No	Yes	Drums

All participants completed every task in the assessment protocol. Assessment results include the hearing screening, the two-point discrimination disc assessment, detection assessment using Von Frey Hair monofilaments, and discrimination assessment also using Von Frey Hair monofilaments.

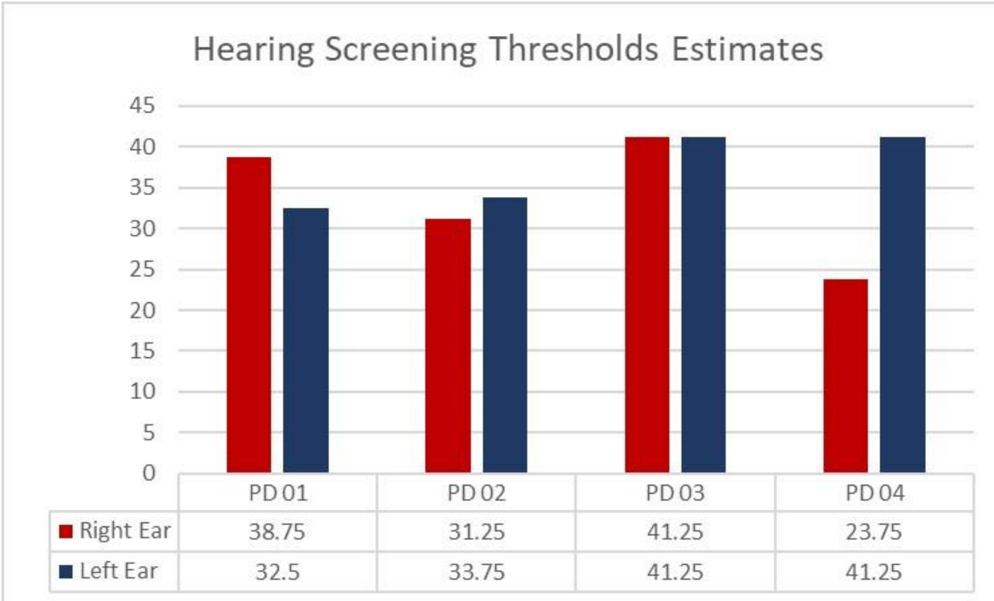
Hearing Screening

The summary of results from the hearing screening can be found below in Table 2. Individual performance for the hearing screening can be found in Figure 1. In Figure 1, the x-axis is the participant code, and the y-axis is the estimated pure tone average measured in decibels. The bars in red represent the data collected for the right ear, and the bars in blue represent the data collected for the left ear. Most of the participants were within the mild hearing loss range (20 to 40 db) with the exceptions of PD03 who was on the cusp of moderate hearing loss in both ears and PD04 who had moderate hearing loss in his left ear ("Degree of Hearing Loss," n.d.).

Table 2. Hearing Screening Threshold

	Right Pure Tone Average (dB)	Left Pure Tone Average (dB)
Minimum	23.75	32.50
Maximum	41.25	41.25
Average	33.75	37.19
Standard Deviation	7.91	4.72

Figure 1. Hearing Screening Threshold



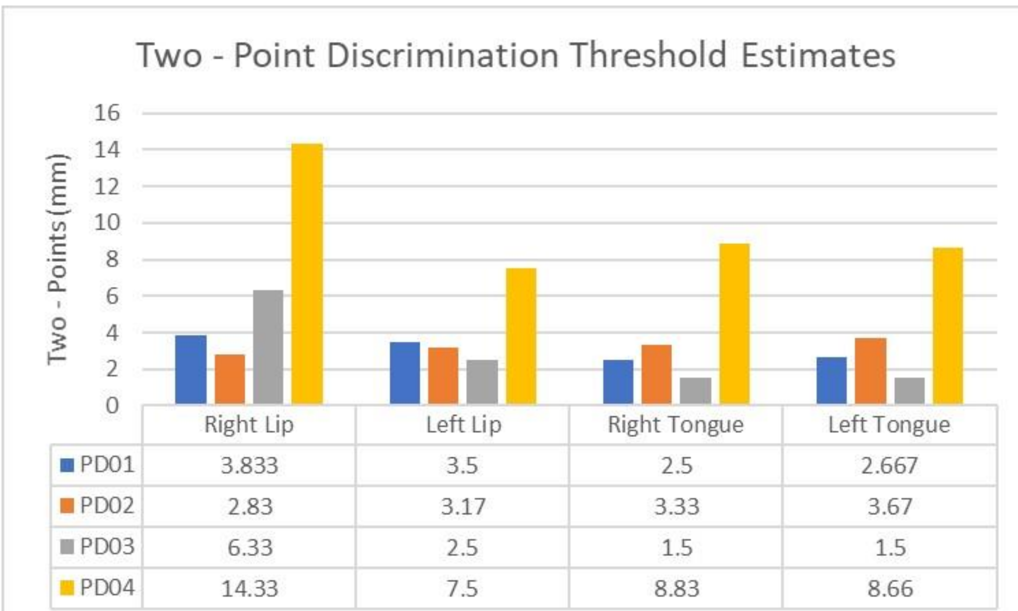
Two-Point Discrimination Threshold Estimates

The summary of results from the two-point discrimination threshold estimates can be found below in Table 3. Individual performance for the two-point discrimination threshold estimates can be found in Figure 2. In Figure 2, the x-axis is the area of the orofacial region tested, and the y-axis is the threshold estimate measured in millimeters (mm). Each partcipant is a different color in the figure. PD01 is blue, PD02 is orange, PD03 is gray, and PD04 is yellow. Each participant completed six acensions and decensions for each orofacial region. The stopping point, or point of discrimination, was recorded and the average was taken for the six trials for each orofacial region and marked as their threshold estimate.

Table 3. Two-Point Discrimination Threshold Estimates

	Two - Point Right Lip (mm)	Two - Point Left Lip (mm)	Two - Point Right Tongue (mm)	Two - Point Left Tongue (mm)
Minimum	2.83	2.50	1.50	1.50
Maximum	14.33	7.50	8.83	8.66
Average	6.83	4.17	4.04	4.12
Standard Deviation	5.21	2.26	3.28	3.15

Figure 2. Two-Point Discrimination Threshold Estimates



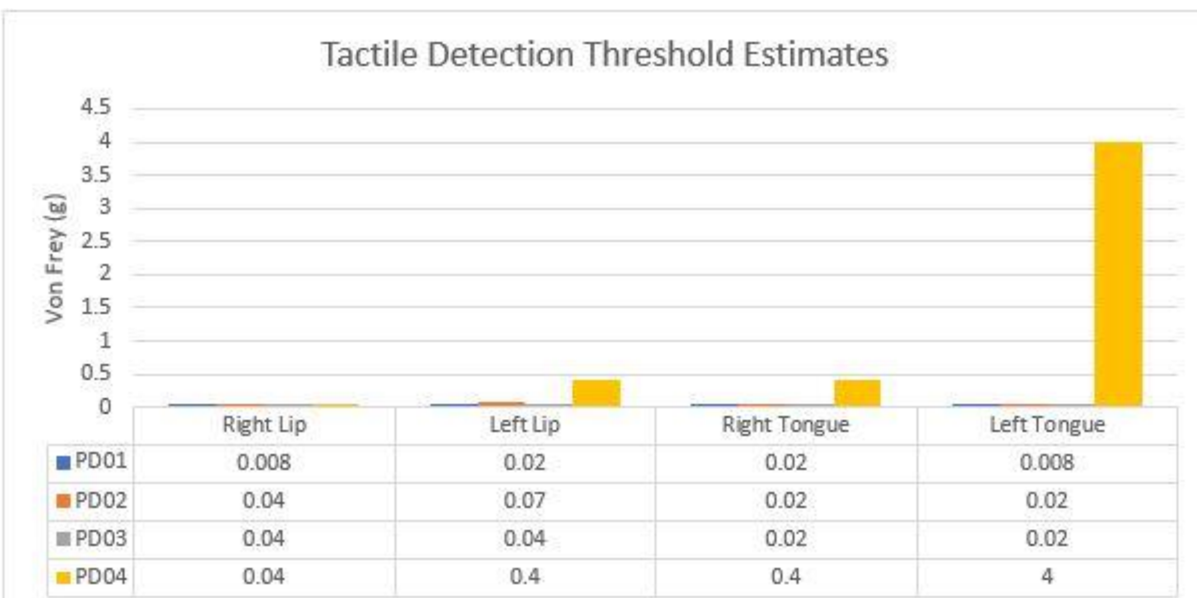
Tactile Detection Threshold Estimates

The summary of results from the tactile detection threshold estimate can be found below in Table 4. Individual performance for the tactile detection threshold estimate can be found in Figure 3. In Figure 3, the x-axis is the area of the orofacial region tested, and the y-axis is the threshold estimate measured in grams (g). Each partcipant maintained the color assigned to them from the two-point discrimination threshold testing figure (Figure 2). Each participant experienced tactile force from Von Frey Hair monofilaments through a series of trials with acensions or decensions until a target force was reached five times. When a target force was met for the fifth time, this force became the participant's threshold estimate for the tested region.

Table 4. Tactile Detection Threshold Estimates

	Detection Right Lip (g)	Detection Left Lip (g)	Detection Right Tongue (g)	Detection Left Tongue (g)
Minimum	0.008	0.020	0.020	0.008
Maximum	0.040	0.400	0.400	4.00
Average	0.032	0.133	0.115	1.012
Standard Deviation	0.016	0.180	0.190	1.992

Figure 3. Tactile Detection Threshold Estimates



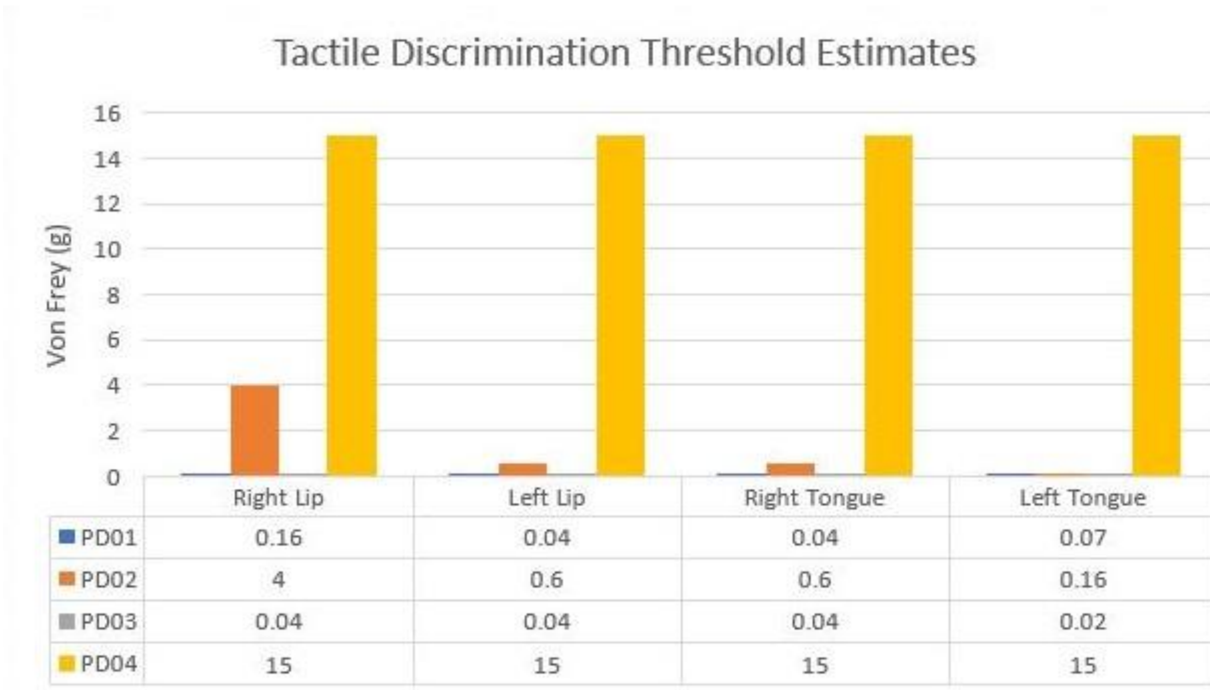
Tactile Discrimination Threshold Estimates

The summary of results from the tactile discrimination threshold estimates can be found below in Table 5. Individual performance for the tactile discrimination threshold estimates can be found in Figure 4. In Figure 4, the x-axis is the area of the orofacial region tested, and the y-axis is the threshold estimate measured in grams (g). Each partcipant maintained the color assigned to them from the two-point discrimination threshold testing and the tactile detection threshold testing. Each participant experienced tactile force from Von Frey Hair monofilaments through a series of trials with acensions or decensions determining the harder force until a target force was reached five times. When a target force was met for the fifth time, this force became the participant's threshold estimate for the tested region.

Table 5. Tactile Discrimination Threshold Estimates

	Discrimination Right Lip (g)	Discrimination Left Lip (g)	Discrimination Right Tongue (g)	Discrimination Left Tongue (g)
Minimum	0.040	0.040	0.040	0.020
Maximum	15.000	15.000	15.000	15.000
Average	4.800	3.920	3.920	3.813
Standard Deviation	7.044	7.391	7.391	7.459

Figure 4. Tactile Discrimination Threshold Estimates



	Right Lip	Left Lip	Right Tongue	Left Tongue
PD01	0.16	0.04	0.04	0.07
PD02	4	0.6	0.6	0.16
PD03	0.04	0.04	0.04	0.02
PD04	15	15	15	15

Chapter 5

Discussion

Research shows that people with Parkinson's disease experience reductions in all five senses: smell, taste, vision, hearing, and somatosensation (Sveinbjornsdottir, 2016). However, literature on somatosensation of people with Parkinson's disease is currently limited. This study aims to add further insight into the feasibility of measurements of somatosensation thresholds in the orofacial region and how potentially higher thresholds can affect speech and swallow functions.

The data collected in this study is compelling and warrants further research on changes in orofacial somatosensation in people with Parkinson's disease. This study is compelling because the threshold estimates vary among participants and the estimates are different than healthy, young adults. The participants with Parkinson's disease demonstrated a wide range of performance variability in their somatosensory threshold estimates, despite them all having Parkinson's disease. For example, ranges in the two-point discrimination threshold estimates were 2.83 mm to 14.33 mm for the right-side of the lower lip. For tactile detection threshold estimates, the range was 0.008 g to 4.00 g for the left-side of the tongue. For tactile discrimination threshold estimates, the range was .020 g to 15.00 g for the left-side of the tongue. With a larger sample size, we could assess if variability is an expected result for orofacial somatosensation in Parkinson's disease. The variability may be due to impaired somatosensation. On the other hand, if somatosensation was not impaired in Parkinson's disease, would there still be variability? Future researchers can answer these questions.

In addition to variability across participants, there are differences when comparing the Parkinson's disease group to healthy, young adults. In a study by Etter et al. (2017), researchers assessed orofacial somatosensation threshold estimates of healthy, young adults using the same assessment protocol used in this study. In the three somatosensation assessments, the healthy, young adults had lower threshold estimates than the participants with Parkinson's disease from this study. For two-point discrimination thresholds, healthy, young adults had an average of 2-3 mm in all locations. Whereas, people with Parkinson's disease in this study had an average of at least 4 mm in all locations. For tactile detection thresholds, healthy, young adults had an average of 0.01g in all locations. Whereas, people with Parkinson's disease in this study had an average of at least 0.03g in all locations. For tactile discrimination thresholds, the healthy, young adults had a maximum average of 0.23g. Whereas, people with Parkinson's disease in this study had an average of at least 3.8g. In all measurements, healthy, young adults had markedly lower threshold estimates than the people with Parkinson's disease. This warrants further studies on the effect age and neurological differences has on orofacial somatosensation. Finally, it is important to note that the participants with Parkinson's disease could complete all tasks, indicating a similar study can be done on a larger scale.

To utilize this study's results, future researchers should collect and compare the data with that of healthy aging controls. By comparing the age-matched participants, researchers will have a better understanding of changes in somatosensation related to age versus disease.

Clinical Applications

Somatosensation research also offers clinical relevance to providing speech therapy services to individuals with Parkinson's disease. Currently, diagnostic assessments for speech and language services do not test somatosensation. However, the tools used in this study, specifically the two-point discrimination discs and Von Frey Hair monofilaments, are portable, easy to use, and cost effective. With proper training, clinicians can implement these assessment measures during diagnostic assessments and treatment sessions. By understanding threshold measurements of people with Parkinson's disease, we can gather more information on specific areas that have lessened sensitivity and see how and if the brain changes from Parkinson's disease affect these less sensitive areas. Assessing orofacial somatosensory thresholds will also help in developing and providing more focused therapy. For instance, speech therapy often uses physical cues for activities, especially in articulation drills where the clinician may ask the client to move their tongue to a certain region of their inner mouth. If the client has decreased sensitivity in the orofacial regions, a physical, oral cue may not be beneficial to the individual. The speech therapist would then need to change stimuli effectively, such as, using auditory cues or pictures instead of physical cues. Somatosensation testing is not only important for individuals with Parkinson's disease but all individuals seeking speech and language services.

Limitations of Study

Hearing screenings were not conducted in a soundproof room. This could have resulted in increased background noise leading to higher estimates than if the screening was done in a soundproof room. However, participants completed hearing screenings in a quiet room using earphone inserts instead of headphones in attempt to mitigate outside noise interference.

Given the approximate length of 1 ½ - 2 hours in combination with the testing measures with small differences, participants may have experienced a fatigue effect. This may have been true for PD04 who reached ceiling levels in the discrimination threshold task, the last assessment. This participant also reached higher levels in the initial regions of the two-point discrimination task due to confusion on directions and responding. To counteract bias results due to fatigue, testing location was randomized.

This study's lab also has a mix of undergraduate and graduate students all participating in data collection. This variety in lab personnel could result in differences in assessment protocols. For instance, although there is an established right lip, left lip, etc. the area tested within those locations may have varied from researcher to researcher. Meaning, one lab personnel could have assessed within the right lip closer to the corner and in the plush area of the lips versus another who could have assessed within the right lip but closer to midline and bottom edge of lip. However, all lab members were trained by the same lab director and monitored for compliance as efforts to control for differences in personnel.

When reaching the lower levels (lesser grams of force required to bend hair) of Von Frey Hair monofilaments, it is more difficult to pinpoint tactile force. There may have been "sliding" in which the hair moved laterally across the orofacial region assessed instead of perpendicularly as protocols intended. This error in testing could result in participants not identifying pressure or guessing on tasks. Participants guessing on tasks could have happened at any point in time throughout the assessment. Unfortunately, this potential error could also be a factor in the data collected.

Furthermore, there is a limitation in the location of this study. Participants were recruited from Center County, PA, where the population is not as high as metropolitan areas. This could have affected the study in many ways. First, it reduced the number of people with Parkinson's disease that could participate in this study. Had this been conducted in a larger metropolitan or a region with a higher density of people with Parkinson's disease, this study could have included more individuals. This affects the study's reliability and generalizability. Given this small population, the study could not control for Parkinson's disease stages. A person with an earlier stage of Parkinson's disease may perform differently than someone at a later stage. Accounting for stage could also impact the intensity of fatigue effect on results. Had this study accounted for this control, there may have only been one or two people with Parkinson's disease included in this study. The study also did not control for any comorbidities that could have affected results.

Future Directions

It is important for future studies to limit errors and account for these controls to ensure a more complete data collection. This study is a beginning to the literature on understanding orofacial somatosensation in people with Parkinson's disease. Furthermore, it is important to conduct more studies with people with Parkinson's disease and compare the results to healthy aging controls. This will allow further knowledge on if and how Parkinson's disease affects individuals' orofacial somatosensation and in turn, functional communication skills.

Appendix A

Health Form Questionnaire

Birthday / Age	
Self-reported Handedness	
Sex	
Occupation	
General health today? (1-5, 5 is best)	
Recent dental work?	
Health of lower face?	
Diabetic? Insulin?	
Ever had a CVA, TIA, or TBI/ABI	
Smoking history? (yes/no)	
If yes, how much? How often?	
If yes or indicates they quit, when was the last time they smoked?	
Any self-reported difficulty hearing…	
…in 1:1 quiet conversation?	
…in noisy environment?	
Do they report wearing hearing aids?	
Bilateral? Left? Right?	
How long have they had aides?	
How often do they wear?	
Ever had difficulty w/ speech?	

Ever played musical instrument?	
If yes, what instrument?	
If yes, for how long?	
If yes or indicate they no longer play, When was the last time they played.	
	Any other comments made by participant:

Appendix B

InterAcoustics AD 629 Audiometer

Appendix C

Speech Usage Scale

Choose the category below that best describes you:

_____ **1. Undemanding:**

Quiet for long periods of time almost every day.

Almost never

• talk for long periods

• raise your voice above a conversational level,

• participate in group discussions, give a speech or other presentation

_____ **2. Intermittent:**

Quiet for long periods of time on many day.

Most talking is typical conversational speech.

Occasionally:

• talk for longer periods

• raise voice above conversational level

• participate in group discussions, give a speech or other presentation

_____ **3. Routine:**

Frequent periods of talking on most days

Most talking is typical conversational speech

Occasionally:

• talk for longer periods

• raise voice above conversational level

• participate in group discussions, give a speech or other presentation

_____ **4. Extensive:**

Speech usage consistently goes beyond everyday conversational speech.

Regularly:

• talk for long periods

• talk in a loud voice

• participate in group discussions, give presentations or performances

The demands of your speech are often high, you are able to continue with most work or social activities even if your speech is not perfect.

_____ **5. Extraordinary:**

Very high speech demands

Regularly:

• talk for long periods of time

• talk with loud or expressive speech or

• give presentations or performances.

The success of your work or personal goals depends almost entirely on the quality of your speech and voice.

Appendix D

Speech Sample Protocol

- **Sustained vowel /a/ and /i/**
  - “Take a deep breath and hold the vowel /xx/ for as long as you can”
  - Repeat x3 for each vowel
- **Sequential Motion Rates (SMRs)**
  - /pa/ /ta/ /ka/
  - “Take a deep breath and repeat /##/ for as long as you can”
  - Repeat with all three CV combinations
- **Alternating Motion Rates (AMRs)**
  - /pataka/
  - “Take a deep breath and repeat /pataka/ as fast/ accurately as possible
- **Automatics**
  - Count 1 -20
    - “Please count 1 to 20”
  - Days of the week
    - “Please say the days of the week starting with Monday”
  - Months of the year
    - “Please say the months of the year starting with January”
- **Word Repetition**
  - Repeat after me
    - Mom
    - Bob
    - Nine
    - Coke
    - Peep
    - Sis
    - Shush
    - Roar
- **Words of increasing length**
  - "I'm going to say some words. You repeat what I say"
    - Thick, Thicken, Thickening
    - Zip, Zipper, Zippering
    - Jab, Jabber, Jabbering
    - Please, Pleasing, Pleasingly
    - Love, Loving, Lovingly
    - Hard, Harden, Hardening
    - Jig, Jiggle, Jiggling
    - Strength, Strengthen, Strengthening
    - Hope, Hopeful, Hopefully
    - Soft, Soften, Softening
- **Repeated Trials/ Multisyllabic words**
  - "I'm going to say some words. I'll say each word one time and then you say it three times"
    - Flashlight
    - Umbrella
    - Newspaper
    - Banana
    - Elephant

- Potatoes
- Butterfly
- Motorcycle
- Computer
- Refrigerator

- **Sentences**
    - Repeat after me:
        - We saw several wild animals
        - My physician wrote out a prescription
        - The municipal judge sentenced the criminal
- **Grandfather Passage**
    - "Here is a short passage that seems a little silly. It was written to include most of the sounds in the English language. Please read the paragraph to me"
        - You wish to know all about my grandfather. Well he is nearly 93 years old, yet he still thinks as swiftly as ever. He dresses himself in an old black frock coat, usually with several buttons missing. A long beard clings to his chin, giving those who observe him a pronounced feeling of the utmost respect. Twice each day he plays skillfully and with zest upon a small organ. Except in the winter when the snow or ice prevents, he slowly takes a short walk in the open air each day. We have often urged him to walk more and smoke less, but he always answers, "Banana oil!" Grandfather likes to be modern in his language
- **Story telling**
    - "Tell me about a vacation you've taken"

Appendix E

Discrimination Discs

Appendix F

Von Frey Hair Monofilaments

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- Working with English Language Learner student on Health Literacy
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