The following individuals certify that they have read, and recommend to the Faculty of Graduate and Postdoctoral Studies for acceptance, a thesis/dissertation entitled:

Auditory function in Parkinson’s disease: preliminary findings

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Won Yong Choi

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Examining Committee:

Dr. Silke Appel-Cresswell, Neurology
Co-supervisor
Dr. Lorienne Jenstad, Audiology and Speech Sciences
Co-supervisor
Dr. Jeff Small, Audiology and Speech Sciences
Supervisory Committee Member
Abstract

Parkinson’s disease (PD) is a neurodegenerative disorder that largely manifests in older adults, whose disease burden may be worsened by age-related conditions like hearing loss. While the effects of PD and hearing loss independently have been studied extensively, evidence on the relationship between hearing and PD is inconsistent and lacking. The primary objective of this pilot study was two-fold: (1) to examine the feasibility of implementing a battery of audiological assessments to participants with PD, and (2) to investigate relationships among the audiological profile, PD symptoms, neuropsychiatric profile, and quality of life in this population. A total of 29 participants was recruited upon referral from the Pacific Parkinson’s Research Centre in Vancouver, BC. Four types of data were collected from each participant: demographic, audiological, neuropsychiatric, and quality of life. The present study found that 65.5% of the participants had normal hearing and that the mean scores of all participants for the neuropsychiatric and quality of life assessments were within normal. However, 58.6% of the participants scored poorer than 2.5th percentile on the Hearing in Noise Test and no participant scored better than the 50th percentile. Poor performance in Hearing in Noise Test was present in most participants, even in normal-hearing participants. PD-related neuropsychiatric and cognitive variables were not correlated with the poor hearing in noise performance. A larger-scale study examining the relationship between PD and hearing seems feasible. Future research on the impact of hearing in noise on communication deficits in PD and possible rehabilitative strategies is paramount.
Lay Summary

Parkinson’s disease (PD) is generally found in older adults, who may experience other health problems that worsen with age like hearing loss. Hearing loss can cause communication breakdowns and distance the person from social interactions, leading to poor quality of health. When a person has both PD and hearing loss, the effects can be devastating. Through this study, we found that a patient with PD can have normal hearing but have problems understanding speech in noise, regardless of the length of time that they have lived with the disease. This finding could affect the testing and rehabilitation for patients with PD. A larger-scale study seems possible and more studies into the relationship between hearing and PD could benefit the patients experiencing communication challenges.
Preface

The identification and design of the research was accomplished through discussion with Drs. Lorienne Jenstad, Silke Appel-Cresswell, and Jeff Small. The compilation of contact list for recruitment and access to the resources at Pacific Parkinson’s Research Centre were provided by the research coordinator, Adam Yu. I was responsible for the recruitment, data collection, and the writing of the thesis. The data analysis was conducted under the support and guidance from Drs. Lorienne Jenstad, Silke Appel-Cresswell, and Maryam Mirian.

The present study received ethics approval from UBC Clinical Research Ethics Board (H17-01296).
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List of Abbreviations

ANSI: American National Standards Institute
ASHA: American Speech-Language-Hearing Association
BDI: Beck’s Depression Inventory
HHIE: Hearing Handicap Inventory for the Elderly
HHIE-S: Hearing Handicap Inventory for the Elderly, screening version
HI: hearing impairment
HINT: Hearing in Noise Test
MoCA: Montreal Cognitive Assessment
NMS: non-motor symptoms
PD: Parkinson’s disease
PPRC: Pacific Parkinson’s Research Centre
PTA: pure-tone average
SAS: Starkstein’s Apathy Scale
SF-36: Medical Outcomes Survey Short Form 36
SIN: Speech in Noise test
SSW: Staggered Spondaic Word test
STAI: Spielberger’s State-Trait Anxiety Inventory
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Firstly, I am grateful to my supervisory committee: Drs. Lorienne Jenstad, Silke Appel-Cresswell, and Jeff Small, for offering me a glimpse into the world of research. I would like to especially thank Drs. Jenstad and Appel-Cresswell for their support and guidance. I am always awe-inspired by the depth and breadth of your knowledge. Without your patience and infectious enthusiasm, this thesis would not be possible. I would also like to thank Drs. Sigfrid Soli and Maryam Mirian for lending me their expertise to gain a better understanding of HINT and data analysis, respectively.

Secondly, special thanks and respects to the participants. Their positive energy and avid interest were the driving force behind this research.

Lastly, I would like to thank my friends and family for supporting me through this journey. It has been a wild ride.
Dedication

To my parents.
Chapter 1: Introduction

Parkinson’s disease (PD) is the second-most common neurodegenerative disorder, affecting more than 100,000 people in Canada and incurring over $201.9 million in direct medical costs (Wong, Gilmour, & Ramage-Morin, 2014). The average age of diagnosis for PD is 60 years and the risk of PD increases with age (Jones, Martin, Wieler, King-Jesso, & Voaklander, 2012). While the current prevalence estimate is 572/100,000 in the North American population over the age of 45, this number is expected to increase as the proportion of the elderly increases (Marras et al., 2018).

PD is most widely recognized by its motor symptoms, manifesting – with varying degrees – as muscle tremors, stiffness, rigidity, and poor balance. Due to the prominence of these motor symptoms, non-motor symptoms (NMS) have been under-appreciated and often undiagnosed, despite occurring in over 90% of patients across all stages of PD (Chaudhuri, Odin, Antonini, & Martinez-Martin, 2011). NMS can also precede motor symptoms by years and correlate with the progression of PD (Martinez-Martin, 2011). In recent years, the presence of NMS, such as pain, cognitive decline, neuropsychiatric symptoms, and sensory impairment, became an emerging issue in clinical and public health for its impact on quality of life (Chaudhuri et al., 2011). Research has shown that NMS progression strongly contributes to the decline in the patient’s health-related quality of life, even more than the motor symptoms (Martinez-Martin, Rodriguez-Blazquez, Kurtis, Chaudhuri, & NMSS Validation Group, 2011). The present study focuses on the relationship between auditory impairment and PD, which has begun to gain attention in literature.
1.1 Purpose of the Study

The primary objective of the study was to determine the feasibility of whether or not it would be possible to recruit participants with Parkinson’s disease and have them complete a battery of audiological assessments, given our time window and the motor symptoms of PD. The outcomes of interest included recruitment rate, dropout rate, time for task completion, practicality of the tasks, and management of the protocol. The secondary objective of the study was to identify the proportion of PD patients with hearing loss to gain a better understanding of hearing loss (HL) prevalence in the sample demographic. The tertiary objective was to explore the potential relationship of hearing loss with cognitive function, anxiety, apathy, depression, quality of life, and disease progression. The findings from this study will guide future, larger-scale studies to systematically evaluate the impact of hearing loss on the PD population in the community, and eventually to develop targeted interventions and identify relevant outcome measures for intervention studies.

1.1.1 Significance of the Research

Much of the relationship between hearing loss and PD is not well understood to date, due to conflicting data and underestimated epidemiological information. However, the invisible burden of hearing loss in all populations is starting to gain attention due to its considerable clinical implications. The identification of hearing loss in the Vancouver PD sample can help to contribute to a better understanding of the complete disease profile of PD, as well as to developing habilitative and counselling approaches that will enhance the care of existing and new PD patients. Furthermore, tailoring interventions to include non-motor symptoms of the
disorder could also improve the patient’s quality of life, fostering the potential for delivering holistic care that addresses psychosocial health.

1.2 Literature Review

1.2.1 Hearing Impairment and Parkinson’s Disease

A large body of research is dedicated to understanding the physiology and impact of PD. Additionally, the negative consequences of undiagnosed and unmanaged hearing loss such as social withdrawal, depression, and lower quality of life are well-documented. However, the evidence that is available to date on the association between hearing impairment and PD is sparse and conflicted. Some researchers have found elevated audibility thresholds at high frequencies (Ali, 2016; Vitale et al., 2012; Yýlmaz et al., 2009); Pisani et al. (2015) and Folmer, Vachhani, Theodoroff, Ellinger, and Riggins (2017) found statistically significant elevation at mid frequencies; but Fradis et al. (1988) did not find a significant difference in the PD patients when compared to the normative values for healthy age- and sex-matched controls. Some studies also report a significant correlation between audiometric results and disease duration and/or the stage of manifestation (Ali, 2016; Pisani et al., 2015; Vitale et al., 2012). The patient’s ability to discriminate speech was also associated with the disease stage (Vitale et al., 2016). Moreover, Lai, Liao, Lin, Lin, and Sung (2014) found an overall 53% excess risk of PD among the hearing loss group compared to the normal-hearing individuals. Interestingly, despite these findings, PD patients often report no perceived hearing disability (Pisani et al., 2015; Rabelo, Lopes, Corona, Araújo, & Nóbrega, 2018; Vitale et al., 2012), suggesting a lack of awareness regarding the non-motor, auditory symptoms in clinical settings. Even though a strong and positive correlation was
Inconsistencies are found in electrophysiological studies as well. Several studies that investigated auditory brainstem responses have reported a significant increase in the wave V peak latency and the interpeak latencies of wave I-V and III-V (Ali, 2016; Hassan & Shalash, 2017; O'Donnell, Squires, Martz, Chen, & Phay, 1987; Tachibana, Takeda, & Sugita, 1989; Yýlmaz et al., 2009) in PD patients. On the other hand, researchers have also found normal auditory brainstem responses in PD patients that do not differ from those of healthy controls (Vitale et al., 2012; Yýlmaz et al., 2009). In some cases, the conflicting results are attributed to the limited sample size and methodological differences, such as selection criteria, outcome of interest, and medicated state of the participants. However, most appear to agree that hearing loss is affected by the pathophysiology of PD, even before any motor symptom may present.

Two main ideas have been summarized by Vitale et al. (2016) concerning the relationship between hearing loss and PD. The first hypothesis focuses on the increased susceptibility of auditory transduction system to aging effects that may be accelerated or exacerbated by the PD-related biochemical changes, like the aggregation of alpha-synuclein in the stria vascularis that mirrors the vascular presbycusis often observed in older adults with cardiovascular problems. The second hypothesis involves more central auditory processing challenges affected by the pathophysiology of PD, particularly with respect to the role of the basal ganglia in controlling or gating the auditory signals.
1.2.2 Adverse Effect of Hearing Impairment on Communication

Hearing impairment has been associated with depression (Dawes et al., 2015; Kvam, Loeb, & Tambs, 2007), anxiety (Kvam et al., 2007), negative emotional reaction (Sugawara et al., 2011; Turner & Beiser, 1990), social isolation or functional limitation (Agmon, Lavie, & Doumas, 2017; Dawes et al., 2015; Sugawara et al., 2011), and cognitive decline (Dawes et al., 2015; Lin et al., 2011). These effects can also be observed in PD.

Hearing impairment (HI) can result in difficulty detecting and localizing sounds, understanding speech in noise, and increased fatigue experienced by the hearing-impaired person as greater concentration is required to make sense of the auditory scene. As the demand and stress increases for both the person with HI and the conversation partner, communication failures can occur and gradually lead to withdrawal from participation in social activities. The lack of social and cultural stimulation for a person with HI can also increase the risk of depression.

These negative consequences of hearing impairment can aggravate disease progression and management of symptoms for people with chronic conditions (Ciorba, Bianchini, Pelucchi, & Pastore, 2012; Dalton et al., 2003). The outcomes may be even poorer in the PD population because several PD symptoms further impair the effectiveness of the patient’s communicative ability, such as apathy, dysphonia, cognitive challenges, anxiety and hypomimia, even for those receiving anti-parkinsonian therapies (Chaudhuri, Healy, & Schapira, 2006; Dirnberger & Jahanshahi, 2013; Lin et al., 2011). Furthermore, the reduced cognitive performance associated with both hearing impairment and PD may result in reduced self-efficacy. This can undermine a person’s belief in his or her ability to complete tasks and achieve goals, which can eventually weaken motivation (Dawes et al., 2015; Dirnberger & Jahanshahi, 2013). Clinically, this implies
that patient’s compliance and symptom management, which are common indicators of effective intervention, may be affected.

The association between PD and hearing impairment requires a closer examination because both conditions significantly affect the growing aging population, yet we presently know little about the extent of their effects and potential relationship; older adults may be exposed to a greater risk of adverse health outcomes if there is a greater risk of hearing loss in the PD population that so far has not been recognized or treated (De Lau & Breteler, 2006; Quaranta et al., 2015). The small body of existing and conflicting literature also calls for prospective studies. A feasibility model was applied to the present study to gain a better understanding of the study’s parameters and the viability of the protocol, with intent to use the findings to plan a future prospective study.

1.2.3 Feasibility

Feasibility studies can take on many names, such as pilot studies, clinical trials, and proof-of-concept. Various definitions exist to describe the methodology (Arain, Campbell, Cooper, & Lancaster, 2010; Arnold et al., 2009; Lancaster, Dodd, & Williamson, 2004), but the commonly shared purpose of a feasibility model is to test a part or the whole study protocol in a smaller scale. The intent behind this approach may be to refine the research question; to determine the reliability, feasibility, and validity of the research design; or to evaluate the effectiveness or safety of an intervention (Thabane et al., 2010).

1.3 Conceptual Definitions

Descriptions of each of the dependent and independent variables relevant to the current study are provided below, as explained in the literature.
1.3.1 Measure of Hearing Impairment: Pure-Tone Audiometry

The definition of hearing loss is broad and subjective. A person may define hearing loss as an absence of hearing, while another would perceive it as any noticeable depreciation in the hearing quality. For this reason, pure-tone audiometric results like audiogram and pure-tone average are helpful in providing an objective measure of hearing that allows for direct comparison with limited bias.

Pure-tone audiometry measures the lowest hearing threshold, as expressed by standardized decibel units (dB HL), that can be perceived by an individual at a specific frequency. Lower thresholds represent better hearing at a particular frequency. These thresholds are plotted on an audiogram, on which intensity is plotted as a function of frequency. The test frequencies typically range from 250 to 8000 Hz, and Table 1 illustrates how hearing thresholds are commonly classified in today’s audiological practice. Audiograms and classification of hearing loss mainly describe a person’s hearing profile and fail to provide a dichotomized definition of whether a person has a hearing loss. The audiogram results are also interpreted according to specific frequency, which means a person may have hearing loss at one frequency but not at another. To address this issue, pure-tone averages are often used in research.
Table 1. Classification of hearing loss

<table>
<thead>
<tr>
<th>Degree of hearing loss</th>
<th>Hearing loss range (dB HL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>-10 to 15</td>
</tr>
<tr>
<td>Slight</td>
<td>16 to 25</td>
</tr>
<tr>
<td>Mild</td>
<td>26 to 40</td>
</tr>
<tr>
<td>Moderate</td>
<td>41 to 55</td>
</tr>
<tr>
<td>Moderately severe</td>
<td>56 to 70</td>
</tr>
<tr>
<td>Severe</td>
<td>71 to 90</td>
</tr>
<tr>
<td>Profound</td>
<td>91+</td>
</tr>
</tbody>
</table>

*As adopted by American Speech-Language-Hearing Association (Clark, 1981)

1.3.1.1 Pure-Tone Average

A pure-tone average (PTA) is a mean value of hearing thresholds at select frequencies. The frequencies used in the average – like the definition of hearing loss – vary somewhat in literature. A classic three-tone PTA uses thresholds from 500, 1000, and 2000 Hz, whereas American Academy of Otolaryngology-Head and Neck Surgery uses a four-frequency average of 500, 1000, 2000, and 3000 Hz (Kim et al., 2016). Alternatively, researchers investigating effects on higher frequencies have used high-frequency PTA at 2000, 3000, 4000, and 6000 Hz (Amos & Humes, 2007; Glista et al., 2009). The Scientific Committee on Emerging and Newly-Identified Health Risks (2008) proposed classifying hearing loss using a speech-frequency PTA of the better-hearing ear, which uses 500, 1000, 2000, and 4000 Hz. They also used the conventional cut-off of 25 dB HL to determine normal hearing from hearing impaired.
The use of speech-frequency PTA has been supported by many researchers because it adds high frequency to the 3-frequency PTA calculation (Anjos, Ludimila, Resende, & Costa-Guarisco, 2014). The inclusion of high frequency has two main benefits: high frequencies are usually the first to be affected in auditory pathologies, so the measure would be more sensitive; and chief consonants of speech intelligibility are located above 2000 Hz, so the measure would offer a better depiction of the person’s ability to recognize speech, which is a common complaint in age-related hearing loss.

1.3.2 Functional Measure of Hearing Impairment

Unlike audiograms, subjective hearing assessments and hearing in noise tests offer a more functional description of a person’s hearing. For example, a person considered to have a moderate degree of hearing loss based on the numeric values may not perceive any hearing difficulty; conversely, a person with normal hearing may experience a significant amount of hearing problems. Therefore, functional measures provide a measure of the patient’s experience and the perceived burden.

1.3.2.1 Self-Awareness of Hearing Impairment: Hearing Handicap for the Elderly

Self-assessment of hearing loss provides a more representative illustration of the auditory scene, or daily listening situation. An example of this is the Hearing Handicap Inventory for the Elderly Screening Version (HHIE-S; Weinstein & Ventry, 1983), which is a screening tool that is most commonly used to determine the subjective effect that hearing loss has on a person’s social and emotional function (Wiley, Cruickshanks, Nondahl, & Tweed, 2000). It is comprised of 10 items that are self-administered and requires about two minutes to complete (Spiby, 2014). The score range for the questionnaire is 0 to 40, and a higher score indicates a greater burden and
A higher probability of hearing loss. A score greater than 8 is the typical clinical cut-off where an audiological referral is recommended (Weinstein & Ventry, 1983).

1.3.2.2 **Hearing in Noise**

For this study, functional hearing performance was measured with the Hearing in Noise Test (HINT; Nilsson, Soli, & Sullivan, 1994) and used as the main dependent variable. HINT measures the sentence reception threshold in speech-weighted noise that would be required to get 50% of the target words correct from a list of 20 sentences (Duncan & Aarts, 2006). The sentences are randomly chosen from a bank of 250 sentences that have been phonemically balanced and tested for reliability (Nilsson et al., 1994). The HINT uses an adaptive method in controlling the presentation level of the target sentence. An ascending approach establishes the starting presentation level, where the participant can repeat all the target words in the sentence correctly. From the second to the fourth sentence, the presentation levels are adaptively increased or decreased in 4-dB steps; and from the fifth to the twentieth sentence, presentation levels are adaptively increased or decreased in 2-dB steps. The target sentences are presented from 0° (directly in front), while speech-spectrum noise is presented from three different positions: 0° (directly in front), 90° (right), and 270° (left).

The scores are expressed as the decibel difference between signal and noise, or the signal-to-noise ratio (dB SNR), with lower and more negative values indicating a better hearing in noise performance (i.e., the listener was able to hear the sentence in a greater amount of noise). In contrast to the conventional speech audiometry, changing the location of the noise source in HINT engages central auditory function because the listener has to utilize dichotic information; two different sounds are presented to each ear, and the timing, amplitude, and
spectral differences between the ears are processed and integrated centrally. For the present study, the average sentence reception threshold across all noise conditions has been used for analysis, which is calculated by the following equation:

\[
\text{Composite SNR} = \frac{[(2 \times \text{Noise Front}) + \text{Noise Left} + \text{Noise Right}]}{4}
\]

1.3.3 PD-Related Neuropsychiatric Characteristics

Five variables related to hearing impairment and non-motor symptoms (NMS) of PD are described below. Other participant characteristics that we used for analysis include age, gender, age of symptoms onset, and disease status. The selected health measures were chosen because they met the criteria: (1) previously applied in the PD demographic or widely used to be comparable, and/or (2) easily administered by a non-clinician with appropriate validity in older adults.

1.3.3.1 Cognition: Montreal Cognitive Assessment

Montreal Cognitive Assessment (MoCA; Julayanont & Nasreddine, 2017; Nasreddine et al., 2005) is a validated tool that measures the global cognitive function, with a higher score representing a better cognitive ability. It is often used to screen for dementia and mild cognitive impairment (Mast & Gerstenecker, 2010), and has been successfully implemented in people with PD (Gill, Freshman, Blender, & Ravina, 2008). A clinical cut-off of 26 and higher is typically used to screen for normal cognitive function. However, a score of 21 or higher was used as a passing standard for the present study to include participants who may have mild cognitive impairment (Biundo, Weis, & Antonini, 2016; Chou, Lenhart, Koepppe, & Bohnen, 2014; Dalrymple-Alford et al., 2010). The cut-off value had been adjusted because mild cognitive
impairment may be present even at the time of PD diagnosis, and it would not have interfered with the participant’s ability to complete their tasks (Hu et al., 2014; Skorvanek et al., 2018). Mild cognitive impairment is a heterogeneous condition that may show some compromised cognitive functions, such as memory, executive function including attention, and/or visuospatial processing, without significantly impacting function in daily life (Aarsland, Brønnick, & Fladby, 2011; Goldman & Litvan, 2011; Litvan et al., 2012).

1.3.3.2 Health-Related Quality of Life: Medical Outcomes Survey Short Form 36

Medical Outcomes Survey Short Form 36 (SF-36) is a self-administered survey that evaluates four physical and mental dimensions respectively: (1) physical functioning; (2) role restrictions due to physical health problems; (3) bodily pain; (4) general health; (5) vitality/energy; (6) social functioning; (7) role restrictions due to emotional problems; and (8) mental health (Steger, 2013; Ware Jr & Sherbourne, 1992). The raw scores are converted into weighted averages, which are then represented as percentages. A higher percentage indicates a better health quality, as perceived by the individual. This survey has been selected because of its wide application and a large body of research dedicated to its usage, which would allow for a direct comparison of the scores to that of the general population.

1.3.3.3 Depression: Beck’s Depression Inventory

Beck’s Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) is a 21-item, self-rated depression scale that has been adopted as a screening tool for this study. Beck’s Depression Inventory (BDI) has been validated and widely used in both non-PD and PD populations (Levin, Llabre, & Weiner, 1988; Visser, Leentjens, Marinus, Stiggelbout, & van Hilten, 2006). The items are scored on a 4-point Likert-type scale (0 to 3), with total scores
ranging from 0 to 63; a higher score represents more severe depressive symptoms. A cut-off value of greater than 14 in the absence of suicidal ideation has been implemented in this study, as supported by Visser, Leentjens, Marinus, Stiggelbout, and van Hilten (2006) and Schrag et al. (2007) for application to the PD demographic.

1.3.3.4 Apathy: Starkstein’s Apathy Scale

Starkstein’s Apathy Scale (SAS; Starkstein et al., 1992) is a variation of Marin’s Apathy Evaluation Scale (Pedersen et al., 2012). It is self-administered and has 14 items that capture a person’s symptomatology over the past four weeks. The items are assessed according to a 4-point Likert-type scale with endpoints of *not at all* and *a lot*. Items 1 through 8 are scored 3, 2, 1, and 0 respectively, and the scores are reversed for items 9 through 14. The scores range from 0 to 42, and a higher score represents more severe apathy. A clinical cut-off of 14 or higher has been used to dichotomize apathetic and non-apathetic participants (Serrano-Dueñas, Martínez-Martín, Merchán, Bravo, & Serrano, 2013). Starkstein’s Apathy Scale has been selected for use in the study because it had been developed to reduce the task completion burden of the original Apathy Evaluation Scale on the PD population (Leentjens et al., 2008).

1.3.3.5 Anxiety: Spielberger’s State-Trait Anxiety Inventory

State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) has a total of 40 items, which are equally divided into two subtests. The first subscale evaluates the “state” or the nervousness and tension felt by the participant at the moment; the second subscale evaluates the “trait” or the general disposition of the participant that makes the person prone to anxiety, like calmness and confidence (Julian, 2011). The responses are based on a 4-point Likert-type scale, some of which are reverse-scored. The total score can range from 20
to 80 per subtest, with a higher score indicating greater anxiety. The scores are summed and displayed in percentile or standard score distributions. The questionnaire has been widely used with good validity and reliability, with the advantage of the scale not focusing as much on the somatic symptoms of anxiety, which is likely to increase in older adults as their health becomes compromised (Bergua et al., 2012; Potvin et al., 2011). Another advantage is that it is easy to administer despite its comprehensiveness, estimated to take approximately 15 to 20 minutes (Potvin et al., 2011). The scores have been left as a continuous variable for analysis, but a cut-off value of 39 or higher for the state scale (Rutten et al., 2017) and 42 or higher for the trait scale (Hanna & Cronin-Golomb, 2012) have been used in tables and scatterplots for illustration purposes (see Table 6, Table 7, Figure 8, & Figure 9).
Chapter 2: Materials and Methods

Chapter 2 explains the methodology with which the study was conducted. The Clinical Ethics Board at University of British Columbia in Vancouver reviewed and approved the study.

2.1 Recruitment

Participants were recruited from the research department at the Pacific Parkinson’s Research Centre (PPRC) in Vancouver, British Columbia. A research coordinator from PPRC provided contact information for patients who had previously consented to being contacted for research purposes and who also met the eligibility criteria. Only the patients who met the inclusion and exclusion criteria were invited to participate. The inclusion criteria required that all participants be age 40 or older, able to understand English instructions and consent, and able to visit the study site at University of British Columbia’s Vancouver campus. The exclusion criteria screened out patients who were diagnosed with dementia or unable to provide informed consent, have a family history of hearing problems, report complications that prevent assessment, and take or have taken ototoxic medication in large doses or for a long duration.

Figure 1 illustrates the screening and recruitment process. Between January 2017 and January 2018, 968 patients with PD were seen at the PPRC and 703 of them had previously consented to being contacted for research opportunities. The coordinator had then pseudo-randomly compiled a list of 200 patients for the researcher to contact by telephone, based on the feasibility of a three-month study completion window. Each patient was contacted three times at most, and no message was left unless explicit verbal consent was obtained via phone. From the list, 94 patients could be reached, and of those, four patients were not eligible, and 61 patients declined to participate for reasons such as health issues, access to the facility, and scheduling
conflicts. After the initial telephone contact, the participants could choose to correspond by telephone or e-mail. In the end, 29 participants completed the study procedure. The recruitment took place concurrently with the data collection, over a period of 18 weeks, from October 13, 2017 to February 8, 2018. A sample of the consent form, containing the information provided to the participants, is in Appendix A.
Figure 1. Flowchart describing the participant recruitment process

Patients with PD seen between January 2017-2018 (n = 968)

Signed a Permission to Contact for research (n = 703)

Pre-screened for eligibility (n = 698)

Excluded (n = 5)
Age < 40 (n = 3)
Deceased (n = 2)

Contacted for study enrollment (n = 200)

Not reached (n = 106)

Reached (n = 94)

Did not meet requirement (n = 4)

Declined (n = 61)
Health issue (n = 3)
Mobility issue (n = 2)
Distance (n = 24)
Scheduling conflict (n = 13)
More than one reason (n = 5)
Not interested/no reason (n = 14)

Participated (n = 29)
2.2 Participants

Twenty-nine participants were enrolled in the study and four of them wore bilateral amplification. There were 18 men and 11 women, and their ages ranged from 49 to 78 years, with the mean age of 66 years. All participants on treatment were assessed in a clinical on state, which is a time when the patients feel that the medication is effective, and their symptoms are improved. Four participants were PD treatment-naïve, i.e. not taking dopaminergic medication, which is often prescribed to treat PD-related symptoms. Most participants \((n = 17)\) were at the second stage of Hoehn and Yahr scale, which indicates bilateral involvement of symptoms without impaired balance. Table 2 describes these participant characteristics.
## Table 2. Participant characteristics

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>Age</th>
<th>Gender</th>
<th>HA user</th>
<th>On medication</th>
<th>Onset (years)</th>
<th>H&amp;Y</th>
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</thead>
<tbody>
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<td>Y</td>
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<td>Y</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note. HA: hearing aid; Onset: number of years since the onset of PD symptoms; H&Y: Hoehn and Yahr scale; M: male; F: female; N/A: information not available*
2.3 Instrumentation

2.3.1 Montreal Cognitive Assessment

The Montreal Cognitive Assessment (MoCA) was administered as directed. The participants took approximately 10 minutes to complete the MoCA. The researcher scored the activity sheet immediately upon completion to determine the participant’s eligibility.

2.3.2 Intake Questionnaire

All participants were given a printed copy of the intake questionnaire, which asked for information on the following: age, gender, disease profile (e.g., number of years since the onset of PD symptoms and any medical conditions apart from PD), and hearing history (e.g., self-awareness of hearing problem; screening questions for genetic, noise-induced, traumatic, or ototoxic hearing loss; and hearing aid usage). Some probing and clarification were used to obtain sufficient detail for each question. At the participant’s request, the researcher would fill in the form if needed. The intake questionnaire took approximately 10 minutes to complete. A copy of the intake questionnaire can be found in Appendix B. Information like the number of years since the onset of PD were provided by the PPRC coordinator from the participant’s clinical chart and took precedence over self-report.

2.3.3 Hearing Handicap Inventory for the Elderly, Screening Version

A screening version of the Hearing Handicap for the Elderly (HHIE-S) was provided to the participant in a printed format. The participants were asked to complete the questionnaire on their own and took approximately three to five minutes. If a participant wore hearing aids, he or she was asked to answer the way they would hear without amplification.
2.3.4 Pure-Tone Audiometry

Pure-tone audiometric testing was completed using a Grason-Stadler clinical audiometer (GSI-61) calibrated according to ANSI S3.6-2004 (American National Standards Institute, 2004). Pure-tone air conduction thresholds were obtained using insert earphones (ER-3A) from each ear at both octave and inter-octave frequencies of 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. One participant used supra-aural earphones (Telephonics TDH-50P) for air conduction testing due to excessive wax. Pure-tone bone conduction thresholds were obtained using the RadioEar B-71 bone transducer for 500, 1000, 2000, and 4000 Hz. Thresholds were obtained using the modified Hughson-Westlake procedure (American Speech-Language-Hearing Association, 2005) and recorded on the audiogram. The entire audiometric procedure took approximately 15 to 45 minutes, depending on the participant.

2.3.5 Hearing in Noise Test

The Hearing in Noise Test (HINT) settings and protocols used for this study can be found in Table 3.

Table 3. Settings for Adaptive HINT

<table>
<thead>
<tr>
<th>Settings</th>
<th>Starting speech level (dBA) or starting SNR (dB SNR)</th>
<th>Noise level (dBA)</th>
<th>Initial step size</th>
<th>Final step size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet</td>
<td>20 dBA</td>
<td>N/A</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Noise Front</td>
<td>0 dB SNR</td>
<td>65</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Noise Right</td>
<td>-5 dB SNR</td>
<td>65</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Noise Left</td>
<td>-5 dB SNR</td>
<td>65</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

The sentences and the noise were delivered by the HINT-PV software version 1.0, circumaural headphones (Sennheiser HD 280 Pro), and a PC soundcard. Information such as the
final threshold (dB SNR), estimated words correct rate (%), and variability were recorded at the end of every setting. If the variability was over 2.5 (i.e., wider spread of values), the test for that setting was repeated. The task completion time would vary, depending on the level of instruction required for the participant, number and duration of breaks required, and the number of times the test would have to be repeated due to large variability. On average, the HINT took approximately 20 minutes to complete.

The sound output for the HINT program was calibrated once a month using Larson Davis System 824 sound level meter, AEC101 coupler, and ½-inch microphone. A biologic listening check was performed prior to each appointment.

2.4 Procedure

The privacy and confidentiality of all communication between the researcher and the participant were maintained, in accordance with the protocol outlined in the ethics guideline at University of British Columbia’s Clinical Research Ethics Board. All participants were offered monetary compensation for parking at the time of their visit.

Each participant completed the entire procedure in a single visit, lasting approximately two hours on average. The procedure was divided into three parts that were conducted in a quiet, private room at the Amplification Research Lab at University of British Columbia’s Vancouver campus. The first part was the intake process. Once the researcher obtained informed consent, each participant underwent the intake protocol, which consisted of MoCA, HHIE-S, and an intake questionnaire, which included questions to obtain information on demographics, disease profile, and hearing history. The second part was the hearing test, which began with a cursory otoscopy of the outer ear. Otoscopy was performed on every participant using a Welch Allyn
otoscope. The participant was then led to a sound-treated booth for pure-tone audiometry with air- and bone-conduction. After the thresholds were obtained, the participant was moved out of the booth and seated on a chair, facing away from the computer screen for HINT. For the HINT, participants were asked to repeat the sentence that they hear verbatim. The third and last part was the neuropsychiatric evaluation. The participants were provided with a printed package, comprised of four self-administered questionnaires: SF-36, SAS, BDI, and STAI. The completion of the package would take approximately 20 to 40 minutes, depending on if the participant had any questions about the package or required breaks. The researcher would also review the entire package to confirm that the participant had responded to every question.

In the present study, the calculated percentages for SF-36 were compared to the average Canadian values (Hopman et al., 2000), using two standard deviations as the cut-off. For BDI, one of the questions asked about suicidal ideation, so the survey was reviewed immediately after it was completed. Even if the resulting score did not meet the cut-off (BDI > 14), a prompt support would have been provided if a participant scored 2 or 3 on question 9 about suicidal thoughts or wishes: recommendation for professional counselling and contacting the responsible clinician on the protocol (Dr. Silke Appel-Cresswell).

After all the data were collected, the researcher provided the participant and a significant other with information about their performance on the hearing tests and with general information about hearing health and communication strategies.

### 2.5 Data Analysis

The primary question of feasibility was addressed by monitoring the recruitment process and the completion of each task by the participants. The secondary question of the prevalence of
hearing loss in PD participants was addressed using descriptive statistics. The tertiary question of the relationship between hearing loss and PD involved four different statistical analyses and was addressed using the Statistical Package for the Social Sciences version 24 for Windows and the R statistical programming software (R Core Team, 2013). Firstly, a non-parametric, chi-square analysis was conducted using the average hearing loss data of the Canadian population (Feder, Michaud, Ramage-Morin, McNamee, & Beauregard, 2015) and that of the PD sample, stratified by age groups. Secondly, a Student’s t-test analysis was performed, comparing the HINT scores of the PD sample to the normative mean composite score (Vermiglio, 2008). Lastly, a multiple linear regression analysis was performed using a forward model to determine any significant predictors of the dependent variable, which was the HINT composite score. The resulting association was considered significant if $p < .05$. 
Chapter 3: Results

Chapter 3 describes the findings from the data after conducting descriptive and statistical analyses.

3.1 Feasibility

In this study, a strict protocol was established to determine the feasibility of implementing an audiological research project involving participants with PD. All participants were able to complete all required tasks with varying durations. The fastest time of protocol completion was 1 hour and 15 minutes, and the longest was approximately three hours. The reasons for variation included: number of breaks (none to three times), duration of the breaks (10 to 20 minutes), amount of assistance required when completing the tasks (e.g., repeated instructions and writing in the participant’s stead), and the number of times HINT had to be repeated for reduced variability (none to twice). The completion time also took into account the discussion session at the end of the appointment to review the participant’s audiometric results and to provide information about hearing loss and communication strategies. Only a few accommodations were made to facilitate the participant’s experience, such as breaks between tasks, changing the response method, and instructing the accompanying caregiver. Overall, the entire protocol could be implemented in all PD participants as per expectation.

For recruitment, telephone was used as the initial contact method. This yielded 47% response rate \((n = 94)\), when called from a list of 200 candidates provided by the PPRC. Distance, scheduling conflict, and lack of interest or no stated reason had been the top three rationales provided by the participants when declining to participate in research. In the end, the
recruitment rate was 5.8 participants per month or 1.6 per week, and once the participant completed the procedure, all data were admitted for analysis.

3.2 Prevalence and Degree of Hearing Loss

A speech frequency pure tone average (PTA) for each ear was calculated by taking the mean of air-conduction hearing thresholds for 500, 1000, 2000, and 4000 Hz for each participant ($N = 29$). The PTA was then used to classify the degree of hearing loss using an ASHA guideline (Clark, 1981). From a total of 29 participants, 65.5% ($n = 19$) were identified as having normal hearing in both ears, 31.0% ($n = 9$) had a mild hearing loss in the worse-hearing ear, and 3.4% ($n = 1$) had a moderately severe hearing loss in both ears. The PTA for each participant, grouped by age, is given in Table 4.
<table>
<thead>
<tr>
<th>Age group</th>
<th>Age (years)</th>
<th>HHIE-S (/40)</th>
<th>Speech frequency PTA (dB HL)</th>
<th>HINT (dB SNR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Better ear</td>
<td>Worse ear</td>
</tr>
<tr>
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<td>40</td>
<td>4</td>
<td>6.3</td>
<td>8.8</td>
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<td></td>
<td>49</td>
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<td>7.5</td>
<td>8.8</td>
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<td>0</td>
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Note. Boldface denotes either a clinical significance or that the value falls outside 2 SD of the normative mean. * indicates an outlier. For all variables, increasing value indicates poorer function. The cut-off value for significance was greater than 8 for HHIE-S, above 25 dB HL for PTA, and above -4.6 dB SNR for HINT. Speech frequency PTA: average of pure tone thresholds for .5, 1, 2, 4 kHz; HHIE-S: hearing handicap for the elderly, screening version; PTA: pure tone average; HINT: hearing in noise test composite score.
3.3 Hearing in Noise Test

Individual HINT performance scores according to age group are given in Table 4, and the participant averages can be found in Table 5. Only the composite HINT score, which is a weighted average of all the speech-in-noise scores, is reported here (see 1.3.2.2 for more information on the HINT composite score). When compared to the American English norm (Vermiglio, 2008), 58.6% \((n = 17)\) of all participants performed poorer than two standard deviations, and none performed at or better than the 50th percentile \((-6.4 \text{ dB SNR})\). The variability score for one participant was higher than the cut-off value of 2.0 and the score was determined to be an outlying data point. All statistical analyses involving HINT in this study have been conducted without the outlier, who is identified in Table 4 by an asterisk and demonstrated a significantly greater degree of hearing loss and poorer performance on HINT compared to the rest of the participant pool. The mean composite score accounting for all participants \((N = 29)\) is -3.6 dB SNR \((SD = 3.2)\) and without the outlier \((n = 28)\) is -4.2 dB SNR \((SD = 1.2)\).

3.4 Neuropsychiatric Characteristics

The present study collected information on five neuropsychiatric characteristics: cognition; quality of health; apathy; depression; and anxiety. The scores of each measure are given in Table 6 for individual data organized by age group, and in Table 7 for mean scores in each age group. All neuropsychiatric variables except MoCA and SF-36 follow the same interpretation: a higher value denotes more severe or worse condition. For MoCA and SF-36, the opposite is true: a higher value denotes better health or function.
Due to the cognitive decline often observed in the Parkinson’s demographic, the MoCA cut-off score for study inclusion was set at 21, which resulted in 28% \((n = 8)\) of the participants having a MoCA score consistent with mild cognitive impairment \((21 \leq \text{MoCA} < 26)\). The scores for each subscale of quality of health survey (SF-36) were analyzed and compared to the Canadian population normative data (Hopman et al., 2000), to determine the proportion of the participants who had scores more than two standard deviations from the mean. The proportion of participants with abnormal scores by subscale are as follows: 34% \((n = 10)\) in the role limitations due to physical functioning subscale; 28% \((n = 8)\) in the general health subscale; 17% \((n = 5)\) in the physical functioning subscale and the role limitation due to emotional problems subscale respectively; 7% \((n = 2)\) in the social functioning subscale; and 3% \((n = 1)\) in the energy subscale. All participants scored within two standard deviations of the population average value for the emotional health subscale and the pain subscale of SF-36. Using the score interpretation of Beck’s Depression Inventory \((\text{BDI} > 14)\), 31% \((n = 9)\) of the participants exhibited clinical depression at the time of data collection. On Starkstein’s Apathy Scale, 45% \((n = 13)\) of the participants scored above the cut-off \((\text{SAS} \geq 14)\) that represents a clinical level of apathy. The STAI lacked an appropriate comparative norm because it has not yet been validated in the PD demographic, so the values were not dichotomized and remained continuous. However, a cut-off score of 39 for the state subscale (Rutten et al., 2017) and 42 for the trait subscale (Hanna & Cronin-Golomb, 2012) have been used for illustration purposes in tables and figures (see Table 6, Table 7, Figure 8, & Figure 9). Each subscale had 34% \((n = 10)\) of the participants reporting a clinical level of anxiety, and seven out of these ten participants scored above the cut-offs for both state and trait subscales.
Table 5. Mean audiometric information according to age group

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>All participants (N = 29)</th>
<th>40 to 49 (n = 2)</th>
<th>50 to 59 (n = 4)</th>
<th>60 to 69 (n = 11)</th>
<th>70 to 79 (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>HHIE-S (/40)</td>
<td>5.4</td>
<td>6.1</td>
<td>2.0</td>
<td>2.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Speech-frequency PTA (dB HL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better ear</td>
<td>17.6</td>
<td>11.3</td>
<td>6.9</td>
<td>0.9</td>
<td>19.7</td>
</tr>
<tr>
<td>Worse ear</td>
<td>22.0</td>
<td>12.0</td>
<td>8.8</td>
<td>0.0</td>
<td>24.7</td>
</tr>
<tr>
<td>HINT (dB SNR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite Score</td>
<td>-4.2*</td>
<td>1.2*</td>
<td>-5.3</td>
<td>0.2</td>
<td>-4.4</td>
</tr>
</tbody>
</table>

*Note. Boldface denotes either a clinical significance or that the value falls outside 2 SD of the normative mean. For all variables, increasing value indicates poorer health perception or function. The cut-off value for significance was 10 or above for HHIE-S, above 25 dB HL for PTA, and above -4.6 dB SNR for composite HINT score. Speech frequency PTA: average of pure tone thresholds at .5, 1, 2, 4 kHz; HHIE-S: hearing handicap for the elderly, screening version; PTA: pure tone average; HINT: hearing in noise test composite score; *Outlier (n = 1) removed.
Table 6. Summary of neuropsychiatric data from individual participants, according to age group

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>MoCA (/30)</th>
<th>SF-36 (/100)</th>
<th>Apathy (/42)</th>
<th>Depression (/63)</th>
<th>Anxiety State (/80)</th>
<th>Anxiety Trait (/80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 to 49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>29</td>
<td>45</td>
<td>0</td>
<td>33.33</td>
<td>45</td>
<td>68</td>
</tr>
<tr>
<td>49</td>
<td>29</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>65</td>
<td>52</td>
</tr>
<tr>
<td>54</td>
<td>27</td>
<td>70</td>
<td>0</td>
<td>33.33</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>55</td>
<td>25</td>
<td>85</td>
<td>0</td>
<td>66.67</td>
<td>40</td>
<td>72</td>
</tr>
<tr>
<td>57</td>
<td>26</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>59</td>
<td>23</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>55</td>
<td>52</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>33.33</td>
<td>45</td>
<td>88</td>
</tr>
<tr>
<td>62</td>
<td>27</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>66</td>
<td>29</td>
<td>70</td>
<td>25</td>
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<tr>
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<td>25</td>
<td>60</td>
<td>25</td>
<td>33.33</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>67</td>
<td>29</td>
<td>95</td>
<td>75</td>
<td>100</td>
<td>60</td>
<td>84</td>
</tr>
<tr>
<td>67</td>
<td>28</td>
<td>90</td>
<td>25</td>
<td>100</td>
<td>65</td>
<td>76</td>
</tr>
<tr>
<td>67</td>
<td>26</td>
<td>25</td>
<td>0</td>
<td>33.33</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>67</td>
<td>25</td>
<td>60</td>
<td>0</td>
<td>100</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>68</td>
<td>25</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>60</td>
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<tr>
<td>69</td>
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<td>0</td>
<td>45</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>70</td>
<td>22</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>85</td>
<td>92</td>
</tr>
<tr>
<td>71</td>
<td>27</td>
<td>60</td>
<td>0</td>
<td>33.33</td>
<td>50</td>
<td>60</td>
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<tr>
<td>71</td>
<td>25</td>
<td>55</td>
<td>25</td>
<td>100</td>
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<td>29</td>
<td>70</td>
<td>75</td>
<td>66.67</td>
<td>40</td>
<td>68</td>
</tr>
<tr>
<td>72</td>
<td>28</td>
<td>100</td>
<td>75</td>
<td>100</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>72</td>
<td>24</td>
<td>45</td>
<td>25</td>
<td>100</td>
<td>50</td>
<td>84</td>
</tr>
<tr>
<td>72</td>
<td>27</td>
<td>70</td>
<td>100</td>
<td>100</td>
<td>60</td>
<td>76</td>
</tr>
<tr>
<td>72</td>
<td>23</td>
<td>90</td>
<td>75</td>
<td>0</td>
<td>55</td>
<td>84</td>
</tr>
<tr>
<td>72</td>
<td>28</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>55</td>
<td>80</td>
</tr>
<tr>
<td>73</td>
<td>27</td>
<td>70</td>
<td>50</td>
<td>100</td>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>74</td>
<td>26</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>76</td>
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<tr>
<td>78</td>
<td>26</td>
<td>55</td>
<td>75</td>
<td>100</td>
<td>50</td>
<td>84</td>
</tr>
</tbody>
</table>
Note. Boldface denotes either a clinical significance or that the value falls outside 2 SD of the normative mean (i.e., significantly poorer health or functioning compared to the population). Apathy, depression, and anxiety variables all indicate worse or more severe condition with increasing value. For MoCA and SF-36, increasing value indicates better health or function. The cut-off values for significance were: below 21 for MoCA, 14 or greater for apathy, greater than 14 for depression, 39 or greater for state anxiety, and 42 or greater for trait anxiety. MoCA: Montreal cognitive assessment; SF-36: RAND’s 36-item short-form health survey of subjective quality of health; Physical: physical functioning; RLPF: role limitations due to physical functioning; RLEH: role limitations due to emotional health; Emotional: emotional health; Social: social functioning; General: general health.
Table 7. Summary of mean neuropsychiatric information according to age group

<table>
<thead>
<tr>
<th>Variable</th>
<th>All participants</th>
<th>40 to 49</th>
<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N = 29)</td>
<td>(n = 2)</td>
<td>(n = 4)</td>
<td>(n = 11)</td>
<td>(n = 12)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>MoCA (/30)</td>
<td>26.6</td>
<td>2.1</td>
<td>29.0</td>
<td>0</td>
<td>25.2</td>
</tr>
<tr>
<td>SF-36 (/100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical functioning</td>
<td>70.9</td>
<td>22.8</td>
<td>72.5</td>
<td>38.9</td>
<td>81.3</td>
</tr>
<tr>
<td>Role limitations due to physical health</td>
<td>44.8</td>
<td>41.4</td>
<td>50.0</td>
<td>70.7</td>
<td>25.0</td>
</tr>
<tr>
<td>Role limitations due to emotional problems</td>
<td>65.5</td>
<td>40.3</td>
<td>66.7</td>
<td>47.1</td>
<td>50.0</td>
</tr>
<tr>
<td>Energy or fatigue</td>
<td>54.3</td>
<td>13.6</td>
<td>55.0</td>
<td>14.1</td>
<td>58.8</td>
</tr>
<tr>
<td>Emotional well-being</td>
<td>73.4</td>
<td>13.1</td>
<td>60.0</td>
<td>11.3</td>
<td>68.0</td>
</tr>
<tr>
<td>Social functioning</td>
<td>69.8</td>
<td>21.3</td>
<td>62.5</td>
<td>17.7</td>
<td>68.8</td>
</tr>
<tr>
<td>Pain</td>
<td>65.7</td>
<td>20.5</td>
<td>78.8</td>
<td>30.1</td>
<td>66.3</td>
</tr>
<tr>
<td>General health</td>
<td>56.0</td>
<td>18.5</td>
<td>60.0</td>
<td>28.3</td>
<td>57.5</td>
</tr>
<tr>
<td>SAS (/42)</td>
<td>12.9</td>
<td>6.6</td>
<td>4.0</td>
<td>1.4</td>
<td>13.3</td>
</tr>
<tr>
<td>BDI (/63)</td>
<td>9.7</td>
<td>6.2</td>
<td>12.0</td>
<td>4.2</td>
<td>10.0</td>
</tr>
<tr>
<td>STAI (/80 per subtest)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>35.4</td>
<td>10.7</td>
<td>46.0</td>
<td>14.1</td>
<td>34.0</td>
</tr>
<tr>
<td>Trait</td>
<td>36.4</td>
<td>9.2</td>
<td>44.5</td>
<td>13.4</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Note. Boldface denotes mild cognitive impairment (21 ≤ MoCA < 26), clinical expression of apathy (SAS ≥ 14), and anxiety (STAI state ≥ 39 and STAI trait ≥ 42). MoCA: Montreal cognitive assessment; SF-36: RAND’s 36-item short-form health survey of subjective quality of health; SAS: Starkstein’s Apathy Scale; BDI: Beck’s Depression Inventory; STAI: Spielberger’s State-Trait Anxiety Inventory. Except for SF-36, all variables indicate worse or more severe condition with increasing value. For SF-36, increasing value indicates better health or function.
### 3.5 Comparing the Prevalence of Hearing Loss in Study Participants to the Canadian Population

Table 8. Observed and expected number of participants with hearing impairment

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>40 to 49</th>
<th>50 to 59</th>
<th>60 to 69</th>
<th>70 to 79</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>NH HL</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Expected</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>*</td>
<td>*</td>
<td>2.25</td>
<td>.54</td>
</tr>
</tbody>
</table>

*Note. NH: normal hearing; HL: hearing loss
*Chi-square test could not be performed due to small sample size.

A chi-square analysis was performed to determine whether the observed number of participants with hearing loss is congruent with the expected number based on the Canadian population prevalence (Feder et al., 2015). The result of the chi-square analysis is shown in Table 8: ages 50 to 59, $X^2 (1, N = 4) = 2.250, p = .134, ns$; ages 60 to 69, $X^2 (1, N = 11) = .537, p = .464, ns$; and ages 70 to 79, $X^2 (1, N = 12) = 2.872, p = .090, ns$. Ages 40 to 49 could not be analyzed due to the small sample size. The results indicate that the prevalence of hearing loss in the participants is not significantly different than expected based on Canadian population prevalence.

### 3.6 Comparing the Participant’s HINT to the American English Normative Mean

Table 9 shows the result from a two-tailed, single-sample $t$-test and reports that the average hearing in noise performance in the Parkinson’s participants without the outlier ($N = 28, M = -4.2, SD = 1.3$) is significantly worse than the test’s normative score ($\mu = -6.4$).
Table 9. Student's t-test result comparing HINT composite score to the American English mean (Vermiglio, 2008). Outlier not included (N = 28)

<table>
<thead>
<tr>
<th></th>
<th>Test Value = -6.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td>HINT</td>
<td>9.871</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note. HINT: hearing in noise test composite score

3.7 Regression Analysis between Hearing in Noise Test and the Predictors

Using hearing in noise and 19 other relevant variables, a linear regression analysis was conducted, and its result is illustrated by Table 12. Age and HHIE-S are correlated to HINT in a moderate, positive relationship that is statistically significant at \( r(26) = .43, p = .014 \) and \( r(26) = .36, p = .037 \) respectively; energy and general health, which are two subscales of SF-36, have a moderate, negative correlation with statistical significance at \( r(26) = -.40, p = .021 \) and \(-.34, p = .046\); and the PTA of both better- and worse-hearing ear have large, positive correlations at \( r(26) = .53, p = .003 \) and \( r(26) = .52, p = .003 \).

The linear regression analysis was conducted with HINT and 19 relevant variables, which are listed in Table 12. The results from the forward linear regression are illustrated in Table 10 and Table 11. The analysis revealed a regression model involving two variables that account for a little under half of the variability in hearing in noise \( (R^2 = .42) \), which was statistically significant, \( F(2, 23) = 8.19, p = .002 \). Both the PTA of the better-hearing ear, \( \beta = .55, t(23) = 3.45, p = .002 \), and the general health subscale of SF-36, \( \beta = -.37, t(23) = -2.30, p = .031 \), were found to be significant predictors of hearing in noise. Furthermore, an examination of the squared semi-partial correlations revealed that PTA of the better-hearing ear and the general
health subscale uniquely predicts 30.2% and 13.4% of the variability in hearing in noise, respectively.

Table 10. Summary of forward linear regression analysis with hearing in noise (HINT) and all predictors, after excluding the outlier and missing values

<table>
<thead>
<tr>
<th>Model</th>
<th>$R$</th>
<th>$R^2$</th>
<th>$R^3$</th>
<th>$SEE$</th>
<th>Adjusted $R^2$</th>
<th>Change</th>
<th>F Change</th>
<th>$df_1$</th>
<th>$df_2$</th>
<th>Sig. F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.531a</td>
<td>0.282</td>
<td>0.252</td>
<td>1.04611</td>
<td>0.282</td>
<td>9.428</td>
<td>1</td>
<td>24</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.645b</td>
<td>0.416</td>
<td>0.365</td>
<td>0.96374</td>
<td>0.134</td>
<td>5.278</td>
<td>1</td>
<td>23</td>
<td>0.031</td>
<td></td>
</tr>
</tbody>
</table>

Note. SEE: Standard Error of the Estimate
a. Predictors: (Constant), PTA of the better-hearing ear
b. Predictors: (Constant), PTA of the better-hearing ear, General health

Table 11. Summary of correlational weight with relevant predictors, without the outlier and missing values

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>p</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>β</td>
<td>Zero-order</td>
<td>Partial</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>-5.53</td>
<td>.49</td>
<td>-11.32</td>
<td>.00</td>
<td></td>
</tr>
<tr>
<td>PTA Better</td>
<td>.08</td>
<td>.03</td>
<td>.53</td>
<td>3.07</td>
<td>.01</td>
</tr>
<tr>
<td>2 (Constant)</td>
<td>-4.22</td>
<td>.72</td>
<td>-5.83</td>
<td>.00</td>
<td></td>
</tr>
<tr>
<td>PTA Better ear</td>
<td>.08</td>
<td>.02</td>
<td>.55</td>
<td>3.45</td>
<td>.00</td>
</tr>
<tr>
<td>SF-36, General Health</td>
<td>-.02</td>
<td>.01</td>
<td>-.37</td>
<td>-2.30</td>
<td>.03</td>
</tr>
</tbody>
</table>

Note. Boldface denotes statistical significance, where $p < .05$. 

36
Table 12. Summary of Pearson's correlation with 20 variables, excluding the outlier and missing values (N = 26)

<table>
<thead>
<tr>
<th></th>
<th>SF-36</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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Note. Boldface denotes statistical significance, where p < .05.
HINT: hearing in noise test composite score; Onset: number of years since the onset of PD; H&Y: Hoehn and Yahr scale; HHIE-S: screening version of the hearing handicap for the elderly; PTA Better: pure tone average of speech frequencies (.5, 1, 2, 4 kHz) in the better-hearing ear; PTA Worse: pure tone average of speech frequencies (.5, 1, 2, 4 kHz) in the worse-hearing ear; MoCA: Montreal Cognitive Assessment
score; SF-36: RAND’s 36-item short-form health survey of subjective quality of health; PF: physical functioning subscale of SF-36; RLPF: role limitation due to physical functioning subscale of SF-36; EH: emotional health subscale of SF-36; RLEH: role limitation due to emotional health subscale of SF-36; Energy: energy subscale of SF-36; SF: social functioning subscale of SF-36; Pain: pain subscale of SF-36; GH: general health subscale of SF-36; SAS: Starkstein’s apathy scale; BDI: Beck’s Depression Inventory; STAI-S: state scale of the state-trait anxiety inventory; STAI-T: trait scale of the state-trait anxiety inventory.
Figure 2 and Figure 3 illustrate the relationship described by the regression model. The PTA of the better ear and the general health subscale combined were found to be significant predictors of hearing in noise (HINT). As the hearing in the better ear and general health worsen, so does hearing in noise (PTA↑, general health↓, HINT↑). Other potential predictors, such as age, cognitive score (MoCA), and the severity of Parkinson’s disease symptoms (H&Y), were not significantly related to hearing in noise. The scatterplots showing the relationships between these predictors and HINT can be found in Figure 4 through Figure 16 of Appendix C. Though there was no statistical significance between these variables and HINT, Figure 5 depicted that difficulty with hearing in noise was already observed in early PD. Excluding the outlier (N = 28), 64% (18/28) of the participants had lived for 4 years or less with the disease and of those, 61% (11/18) scored as poor as, or poorer than 2.5th percentile on the HINT.
Figure 2. Relationship between hearing in noise (HINT) and pure-tone hearing threshold in the better-hearing ear (PTA Better) without the outlier ($N = 28$)

Note. Data points that fall within the upper right (red) quadrant represent participants who have unilateral or bilateral hearing loss (PTA > 25 dB HL) and have a HINT score that is poorer than 2 $SD$ from the norm (Vermiglio, 2008). Data points that fall within the upper left (yellow) and bottom right (yellow) quadrants represent participants who either have normal hearing and a HINT score that is 2 $SD$ poorer than the norm (Vermiglio, 2008) or have a hearing loss and a HINT score that is within 2 $SD$ of the norm. Data points that fall within the bottom left (green) quadrant represent participants who have both normal hearing and a HINT score that is within 2 $SD$ of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant ($N = 28$). HINT: Hearing in Noise Test composite score; PTA Better: speech frequency pure tone average of the better-hearing ear.

\[ y = 0.0774x - 5.4523 \]
\[ R^2 = 0.2792 \]
Figure 3. Relationship between hearing in noise (HINT) and general health, without the outlier ($N = 28$)

Note. Data points that fall within the upper left (red) quadrant represent participants who reported general health score that is 2 $SD$ poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 $SD$ poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either have general health within 2 $SD$ of the Canadian average (Hopman et al., 2000) and a HINT score that is 2 $SD$ poorer than the norm, or reported having general health 2 $SD$ poorer than the average (Hopman et al., 2000) and a HINT score that is within 2 $SD$ of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report both general health and HINT score that are within 2 $SD$ of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant ($N = 28$). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: Hearing in Noise Test composite score.
Chapter 4: Discussion

The main objective of the study was to determine the feasibility of conducting a research project examining hearing loss in PD patients. Successful recruitment allowed for two additional inquiries to be made based on the PD participant data: (1) the prevalence of hearing loss in this sample, and (2) the relationship between hearing status and neuropsychiatric factors.

4.1 Feasibility

The feasibility of the study can be considered as highly probable, if the same design were to be applied in a larger scale, though a number of modifications would need to be made. The use of telephone as the initial contact method greatly limited the present study because selection bias likely pervaded the recruitment process, weakening the power of the data. Given that we were looking for Parkinson’s patients who were both normal- and hard-of-hearing, telephone may have narrowed the participant pool to those who have normal hearing or minimal hearing challenge and those living with a caregiver. Also, calls may have been screened by the patient because the number is unfamiliar, and the timing of the calls would have further restricted the chance for recruitment if they did not coincide with the patient’s availability. Two participants had indicated that patients are more likely to check e-mails than voicemails and suggested using a community e-mail thread from Parkinson’s Society to reach a wider pool of candidates.

The top three reasons for declining participation were: distance, scheduling conflict, and lack of interest/no stated reason. While the lack of interest cannot be helped, distance and scheduling all pertain to access to the study site. Because PPRC caters to the entire province of British Columbia, the contact list also included people living on the islands and in remote areas. Three participants with long-distance numbers had declined participation, reasoning that winter
was not a travelling time, so the seasonal timing of the recruitment may also need to be considered when designing studies involving PD participants from this participant pool in the future.

4.2 Prevalence

The prevalence of hearing loss in the PD participants was 13.8% \((n = 4)\), based on the better-hearing ear and 34.5% \((n = 10)\) based on the worse-hearing ear, which was within expectation of the Canadian population prevalence (Feder et al., 2015). Though the present study examined only the prevalence of hearing loss and not frequency-specific thresholds, our finding was consistent with that of Fradis et al. (1988), who found no significant difference in the PTA thresholds of PD patients over 500 to 8000 Hz when compared to healthy controls. In contrast, other researchers have found elevated thresholds in PD participants at low (Pisani et al., 2015), mid (Folmer, Vachhani, Theodoroff, Ellinger, & Riggins, 2017; Pisani et al., 2015), or high frequencies (Di Mauro, Di Lazzaro, Schirinzi, Martino, & Mercuri, 2017; Vitale et al., 2016; Yýlmaž et al., 2009) alongside an age-related hearing impairment. The discrepancy in these pure-tone results and the potential recruitment bias discussed above could be attributed to the small sample size and the comparison group. Both Folmer et al. (2017) and Pisani et al. (2015) had identified small sample size as potential limitations; small sample size can affect the power of the study and pose greater likelihood of increased variability in the data. The studies also varied in terms of comparison group. Unlike other studies that used healthy, age-matched controls, the present study used the general population data (Feder et al., 2015), which did not preclude people with health complications. Thus, hearing in the comparison group may have been poorer than in purposefully selected, age-matched healthy controls, which contributed to the discrepancy.
4.3 Hearing in Noise Test

In addition to pure tone testing, hearing in noise was also measured with HINT to gain a better understanding of everyday listening performance of the individual. The participants were asked to repeat the sentence that they hear – word for word – in different noise conditions and were instructed to guess when they could not make out the words. Such a task also provides an estimation of the person’s central auditory processing capability because it uses bilateral processing of sound intensity and time difference. Unlike the pure-tone results that showed no difference between the PD sample and the Canadian population average, 58.6% \((n = 17)\) of the participants performed significantly worse than norm on HINT (Vermiglio, 2008). Vitale et al. (2016) had included speech audiometry in their test battery to examine the participant’s ability to recognize speech in quiet and suggested a peripheral origin to the hearing impairment in PD patients, given the absence of retro cochlear evidence. However, the authors also posited a top-down hypothesis to explain that PD pathophysiology could be affecting the processing of auditory information. Numerous studies (Folmer et al., 2017; Guehl et al., 2008; Lewald, Schirm, & Schwarz, 2004) provided evidence in support of this theory. A prime example is a recent study by Folmer et al. (2017), which investigated central auditory processing in PD patients. They found that PD patients scored significantly worse than the control subjects in spatial release from masking test when the noise was spatially separated from the signal. This is like the HINT in the present study because both tests assess the listener’s ability to process spectral and spatial cues by employing noise and change in position of the noise source. The distinction of space separation is important because conventional speech intelligibility in noise tests like QuickSIN are limited to addressing the poorer-than-normal signal-to-noise ratio that is experienced by most people with hearing loss.
All analyses involving HINT were conducted with only 28 participants because one participant was identified as an outlier. The outlying participant demonstrated a significantly greater degree of pure-tone hearing loss and the poorest HINT performance compared to other participants. The raw data also showed larger variability in the participant’s HINT responses, which might be due to reduced audibility during testing. For future studies involving HINT, the background noise level could be adjusted to rule out audibility as an issue.

4.4 Hearing in Noise Test and Related Variables

The hearing in noise performance – as represented by the HINT composite scores – of all PD participants was poorer than the normative mean, and over half of the participants fell below the 2.5th percentile. A correlational analysis of hearing in noise and 19 related variables revealed that only PTA of the better ear and the general health subscale of SF-36 explained some of the variance in the hearing in noise results. We were not able to explain the poorer hearing in noise performance in this group by any of the measured PD characteristics like H&Y and duration of the disease burden. However, it is interesting to note that most of the PD sample had poorer than expected HINT scores, despite falling within normal range of hearing and reporting little to no hearing burden. This disconnect between the subjective hearing burden (HHIE-S), objective hearing assessment (PTA), and hearing in noise (HINT) may have been due to the lack of variability in the PD and other neuropsychiatric characteristics within the sample. On the other hand, patients with PD have poor recognition of other sensory and motor deficits like olfaction and hypophonia. It is thus not surprising that there is a discrepancy between the HHIE-S and PTA, given that the same discrepancy is found in healthy older adults as well (Wiley et al., 2000).
4.5 Hearing in Noise Test and PD

Several studies have been conducted to date in order to understand the relationship between hearing and PD, but researchers remain uncertain as to its pathophysiology. Pisani et al. (2015) reported improved audiological responses in PD patients upon dopaminergic treatment, supporting that dopamine plays a modulating role in auditory signal transduction from the afferent dendrites of the inner hair cells. Extending from the periphery, dopamine also affects central executive functions. Georgiev et al. (2015) and Kotz, Schwartze, and Schmidt-Kassow (2009) have identified the lack of dopamine in PD to affect attention-switching ability in the dorsal network, which can impede discrimination of signal from noise. The many roles assumed by dopamine may account for elevated thresholds (Vitale et al., 2012; Yýlmaz et al., 2009), poor auditory processing (Di Mauro et al., 2017), and abnormal auditory brainstem responses (Shalash et al., 2017).

Lewald, Schirm, and Schwarz (2004) have also investigated the auditory spatial perception in PD participants and found that PD participants exhibited significantly greater interaural processing time compared to the age-matched controls; they proposed that the basal ganglia – responsible for temporal processing in the brain – being affected as the potential culprit by comparing the just-noticeable-difference of interaural time to that of healthy controls. A recent study by Folmer et al. (2017) explicitly administered central auditory processing assessments, such as Gap in Noise, Dichotic Digits Test, and spatial release from masking test, and found that participants with PD scored significantly worse on the hearing handicap for adults and spatial release from masking at 45° condition. Similar to our HINT results, Folmer et al. (2017) found that PTA of the worse-hearing ear was significantly correlated with Words in Noise test and Hearing Handicap Inventory for Adults; the spatial release form masking at 45° was also
significantly associated with age. They hypothesized that the central auditory deficits observed in PD participants would worsen with age, which is congruent with the increased susceptibility to aging effects supported by Vitale et al. (2012; 2016). According to our findings, a large number of the participants performed poorly on HINT compared to the norm (Vermiglio, 2008), but our participants were also older than the age group from which the norms were generated. However, the actual performance did not correlate with age (i.e., a younger participant did not score better compared to an older participant) and the limited sample makes it difficult to compare between the age groups to confidently support or contradict the hypothesis.

4.6 Clinical Implications of the Study

The present study found that the prevalence of hearing loss was within the Canadian population prevalence, but the PD participants performed significantly poorer than expected with regards to sentence intelligibility in noise. These findings have three important clinical implications.

Firstly, an audiometric assessment could be beneficial to patients with PD. A PD patient may or may not experience hearing difficulty, especially because one functional ear is sufficient for daily listening activities, so the hearing loss can go unnoticed. Untreated hearing loss can have negative consequences on a person’s social, emotional, and mental well-being that will worsen over time. Likewise, PD can negatively impact a person’s neuropsychiatric conditions. These are all invisible symptoms that can be difficult to ascertain but have a profound effect on a person’s quality of life, thus emphasizing the importance of early detection.

Secondly, a person with PD may not benefit from a standard audiometric assessment alone. The participants who demonstrated normal hearing also exhibited poor auditory processing in noise, so all patients with PD – regardless of their hearing level – could benefit
from an inclusion of speech audiometry involving central auditory processing, such as SIN, HINT, and SSW. Following assessment, the aural rehabilitation could focus on dealing with listening in noise, in addition to restoring audibility.

Thirdly, the impact of hearing difficulty in different noise settings needs to be further examined to improve the communication challenges. Many patients with PD already face significant communication deficits due to dysarthria, hypophonia, social anxiety, cognitive challenges, and hypomimia. Our research found that poor HINT performance was present in most participants, irrespective of the time they have lived with the disease, so if early intervention is possible, rehabilitative strategies will need to address hearing in noise to improve communication deficits as well.

4.7 Improvements for Future Research

The study contained a small sample size, comprised of only PD patients of relatively good health and hearing and with access to transportation. This introduced bias in the selection process and did not provide a sufficiently wide range to explore variability in objective hearing. Despite this possible selection bias towards better hearing, poor HINT performance was found in the majority of PD participants, regardless of their level of hearing. The participants were also screened for cognitive function prior to the hearing test; while the study was done this way to ensure eligibility of the participants, this could be reconsidered in future studies because sensory impairment could have undermined the participant’s cognitive scores (Dupuis et al., 2015). For future research examining hearing loss in PD patients, a greater number of recruits, alternate or multiple contact methods, and a careful consideration of the comparison group may offer more analysis options.
4.8 Conclusion

The present study has demonstrated that the prevalence of pure tone hearing loss in PD patients does not significantly differ from the national prevalence data. However, the prevalence of hearing difficulty in noise in PD participants was significantly greater than the healthy norm. Hearing difficulty in noise did not correlate significantly with the presence of neuropsychiatric and cognitive variables and seems to be an independent symptom of PD, which can be already present at the beginning of disease onset. A larger-scale study examining these relationships is indicated and feasible. Further research on the impact of hearing in noise on communication deficits in PD and possible rehabilitative strategies is paramount.
Bibliography


Julian, L. J. (2011). Measures of anxiety: State-Trait Anxiety Inventory (STAI), Beck Anxiety Inventory (BAI), and Hospital Anxiety and Depression Scale-Anxiety (HADS-A). *Arthritis Care & Research, 63*(S11), S467-S472.


Appendices

Appendix A. Consent Form

Participant Information and Consent Form
PD GROUP

Auditory Function and Cognition in Parkinson's Disease, Feasibility Study

Principal Investigator: Dr. Lorienne Jenstad, PhD, Aud(C), RAUD, RHIP
Faculty of Medicine, School of Audiology & Speech Sciences
University of British Columbia
(604) 822-4716  ljenstad@audiospeech.ubc.ca

Co-Investigators:

Dr. Silke Cresswell  Dr. Jeff Small
Assistant Professor  Associate Professor
Division of Neurology  School of Audiology & Speech Sciences
Faculty of Medicine  University of British Columbia
University of British Columbia  Vancouver, BC, Canada
Vancouver, BC, Canada

Student Investigator:
Mathilda Choi
School of Audiology & Speech Sciences
University of British Columbia
Vancouver, BC, Canada
(604) 827-3338  amplab@audiospeech.ubc.ca

This is a Master’s thesis study conducted as part of a graduating requirement. The collected information will be accessible only to the persons listed above. If you are interested in the findings of this study, please feel free to contact the student investigator.
1. **Invitation**

You are being invited to take part in this research study because you have been referred by the research coordinator at Pacific Parkinson’s Research Centre and shown interest in participating in studies about Parkinson’s disease. You also met the primary eligibility requirements for participation, which included age (≥40), English fluency, physical mobility, and management of Parkinson’s symptoms with medication.

2. **Your participation is voluntary**

Your participation is voluntary. You have the right to refuse to participate in this study. If you decide to participate, you may still choose to withdraw from the study at any time without any negative consequences to the medical care, education, or other services to which you are entitled or are presently receiving.

Please review the consent document carefully when deciding whether you wish to be part of the research, and sign this consent only if you accept being a research participant.

3. **Who is conducting this study?**

This study is not receiving funds from an external agency or sponsor.

4. **Background**

While much research focuses on the motor symptoms of Parkinson’s disease, there is not much information on non-motor symptoms like hearing. We want to learn more about how to help people with Parkinson’s disease, who also experience reduced quality of life and difficulty communicating due to hearing loss.

Eligible participants will have their hearing tested, free of charge, with an optional information session at the end. We are looking for participants with PD and participants without PD. We will recruit up to 100 people per group over the period of 3 months.

5. **What is the purpose of the study?**

A “pilot study” or “feasibility study” is done to test the study plan and to find out whether enough participants will join a larger study and accept the study procedures. This type of study involves a small number of participants and so it is not expected to prove a research hypothesis. The results may be used as a guide for larger studies, although there is no guarantee that they will be conducted. Participation in a pilot study does not mean that you will be eligible to participate in a future larger study. Knowledge gained from pilot or feasibility studies may be used to develop future studies that may benefit others.
This is a feasibility study. A feasibility study is conducted in a small group of people for the first time to assess the coherence of the research question and/or the validity of the study protocols.

The primary purpose of this study is to evaluate the feasibility of the protocol in participants with Parkinson’s disease and if sufficient recruitment will be possible for a larger study. The secondary purpose is to determine the prevalence of hearing loss in people with Parkinson’s disease and if it is related to their demographic or disease profiles.

6. **Who can participate in this study?**

You may be able to participate in this study if you are:
- Aged 40 or older
- English-speaking and literate
- Able to understand instructions and consent
- Physically able to visit the study site
- Diagnosed with Parkinson’s disease
- Currently taking medications for Parkinson’s disease

7. **Who should not participate in this study?**

You will not be eligible to participate in this study if you are:
- Not able to understand or consent to the study, or diagnosed with dementia
- Possess history of persistent hearing problems
- Report extreme sensitivity in ears to the point that assessments cannot be conducted
- Experience combined vision and hearing problems that prevent information collection
- Previously or currently taking medication that can be harmful to hearing (e.g., large-dose aspirin, loop diuretics, aminoglycosides)

8. **What does the study involve?**

**Overall design of the study**

By agreeing to take part in the study, you are committed to a one-time visit that is expected to last approximately 1-2 hours. Your eligibility will be confirmed at the beginning of the visit. If you meet the inclusion criteria, a series of audiological assessments and questionnaires will be administered to determine your hearing status. The audiological assessment may take up to 1 hour and the completion of questionnaires can take up to 1 hour. Participants are not required to answer questions that they are not comfortable answering.
- After assessments, you will be presented with an option to receive information about your hearing and communication strategies.
If You Decide to Join This Study: Specific Procedures
If you agree to take part in this study, the procedures you can expect will include the following:

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</tr>
<tr>
<td>4. Perceived hearing status and activity limitations (HHIE-S)</td>
<td>2-5 minutes</td>
</tr>
<tr>
<td>5. Otoscopy</td>
<td>&lt;1 minute</td>
</tr>
<tr>
<td>6. Tympanometry</td>
<td>10 minutes</td>
</tr>
<tr>
<td>7. Pure-tone audiometry</td>
<td>20 minutes</td>
</tr>
<tr>
<td>8. Hearing in noise test (HINT)</td>
<td>5-10 minutes</td>
</tr>
<tr>
<td>9. Perceived quality of life regarding participant’s health (SF-36)</td>
<td>10 minutes</td>
</tr>
<tr>
<td>10. Assessment for apathy, a non-motor symptom of PD (AS)</td>
<td>10 minutes</td>
</tr>
<tr>
<td>11. Assessment for depression, a non-motor symptom of PD (BDI)</td>
<td>10 minutes</td>
</tr>
<tr>
<td>12. Assessment for anxiety, a non-motor symptom of PD (STAI)</td>
<td>5-15 minutes</td>
</tr>
<tr>
<td>13. Information on communication strategies (optional)</td>
<td>As needed</td>
</tr>
</tbody>
</table>

Use of Data from Secondary Data Sources
The student investigator will coordinate with a PPRC liaison, who will consult the clinical and research records to obtain your information on Movement Disorder Society’s Unified Parkinson’s Disease Rating Scale (MDS-UPDRS), pharmaceutical information, other medical conditions, and number of years since the onset of symptoms. The privacy and confidentiality of this information will be respected and adhered in accordance with the University of British Columbia’s Clinical Research Ethics Board guidelines.

Once the student investigator receives information from the liaison, all personal identifiers like name, age and gender will be removed, and a random code will be assigned. The information will not be shared or transferred to another institution or study.

*By signing the document, you give permission for the student investigator to contact PPRC and for the liaison to release the following information: MDS-UPDRS, list of pharmaceuticals, other medical conditions, and number of years since the onset of PD symptoms.

9. What are the possible harms and discomforts?

There is no harm or side effects expected from the study.

You may feel discomfort from insertion of probe tips in your ear and prolonged seating in a sound-treated room. You are free to take as many breaks as needed and to inform the study staff if you feel uncomfortable for any reason.
Some of the questions we ask may seem sensitive or personal. You do not have to answer any question if you do not want to. Please let one of the study staff know if you have any questions or concerns.

10. **What are the potential benefits of participating?**

You will receive a free hearing test and an optional, customized information session on communication strategies that may help with challenging hearing situations.

We hope that the information learned from this study can be used in the future to guide clinicians’ practice on how they may address Parkinson’s disease patients with hearing loss.

11. **What happens if I decide to withdraw my consent to participate?**

You may withdraw from this study at any time without giving reasons. If you choose to enter the study and then decide to withdraw at a later time, you have the right to request the withdrawal of your information collected during the study. This request will be respected to the extent possible. Please note, however, that there may be exceptions where the data will not be able to be withdrawn. For example, where the data is no longer identifiable (meaning it cannot be linked in any way back to your identity) or where the data has been merged with other data. If you would like to request the withdrawal of your data, please notify the study team.

12. **Can I be asked to leave the study?**

Unless the participant expresses a request for withdrawal, the study investigator will not ask an eligible participant to leave the study.

13. **How will my taking part in this study be kept confidential?**

Your confidentiality will be respected. However, research records and health or other source records identifying you may be inspected in the presence of the investigator and UBC Clinical Research Ethics Board for monitoring the research. No information or records that disclose your identity will be published without your consent, nor will any information or records that disclose your identity be removed or released without your consent unless required by law.

You will be assigned a unique study number as a participant in this study. This number will not include any personal information that could identify you (e.g., it will not include your Personal Health Number, birthdate, or your initials, etc.). Only this number will be used on any research-related information collected about you during the course of this study, so that your identity will be kept confidential. Information that contains your identity will remain only with the Principal Investigator and/or designate. All documents will be identified only by code number and kept in a locked filing cabinet. Subjects will not be identified by name in any reports of the
completed study. Data may also be stored in computerized hard drives, which will be password-protected and stored in a locked filing cabinet in the Amplification research lab in the basement of Woodward library at UBC, which has two locking doors and an alarm system. The list that matches your name to the unique study number that is used on your research-related information will not be removed or released without your consent unless required by law.

Your rights to privacy are legally protected by federal and provincial laws that require safeguards to ensure that your privacy is respected. You also have the legal right of access to the information about you that has been obtained and, if need be, an opportunity to correct any errors in this information. Further details about these laws are available on request.

**Disclosure of Demographic Information**
The study collects information on demographic features, such as age and gender. This information will be used as variables to determine their relationship to disease and hearing profiles in Parkinson’s disease participants, which is the secondary objective of this study.

Providing information on your demography is voluntary.

14. **What happens if something goes wrong?**

By signing this form, you do not give up any of your legal rights and you do not release anyone else from their legal and professional duties.

The study presents minimal risks and does not involve any invasive procedure. The study staff will contact first responders in case of medical emergency (e.g., injury from fall) during data collection. In the event that you are identified to be at a high risk of depression, the study staff will contact the PPRC clinician for a follow-up appointment. A list of community resources will also be made available for you based on the findings from the hearing test and the questionnaires, or upon request.

15. **What will the study cost me?**

All research-related tests that you will receive during your participation in this study will be provided at no cost to you.

**Reimbursement**
Participants may incur parking fees and public transportation costs as a result of participation. These expenses will be reimbursed, upon presentation of proof of purchase (e.g., receipt, transit pass).

**Remuneration**
You will not be paid for participating.
16. **Whom do I contact if I have questions about the study during my participation?**

If you have any questions or desire further information about this study before or during participation, you can contact the student investigator, Mathilda Choi, at (604) 827-3338.

17. **Whom do I contact if I have any questions or concerns about my rights as a participant?**

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the University of British Columbia Office of Research Ethics by e-mail at RSIL@ors.ubc.ca or by phone at 604-822-8598 (Toll Free: 1-877-822-8598). Please reference the study number (H17-01296) when calling so the Complaint Line staff can better assist you.

18. **After the study is finished**

Once your participation has concluded, you can choose to receive information based on the audiological results. Participants may contact the study team at amplab@audiospeech.ubc.ca or (604) 827-3338 to receive research updates and findings.

**Future Contact**

A feasibility study may be followed up for supplemental information or be implemented in a larger scale in the future. If you wish to receive information about future opportunities for research participation, please check the box below.

☐ Yes, I give permission to be contacted to learn about upcoming opportunities to participate in research

Printed Name: ____________________________  Signature: __________________________

Date: ________________

Preferred mode of contact:

E-mail ______________@______________  OR  Telephone ___________________

By ticking the “Yes” box and signing above, I give the study team permission to contact me about participating in future research opportunities, should one arise. I have read and understood that the permission is only to be contacted and not for participation.
19. Signatures

Auditory Function and Cognition in Parkinson’s Disease, Feasibility Study

Participant Consent

My signature on this consent form means:

▪ I have read and understood the information in this consent form.
▪ I have had enough time to think about the information provided.
▪ I have been able to ask questions and have had satisfactory responses to my questions.
▪ I understand that all of the information collected will be kept confidential and that the results will only be used for research purposes.
▪ I understand that my participation in this study is voluntary.
▪ I understand that I am completely free at any time to refuse to participate or to withdraw from this study at any time, and that this will not change the quality of care that I receive.
▪ I authorize access to my records for via liaison at PPRC as described in this consent form.
▪ I understand that I am not waiving any of my legal rights as a result of signing this consent form.

I will receive a signed copy of this consent form for my own records.

I consent to participate in this study.

______________________________  _________________________  _________________
Participant’s Signature        Printed name                 Date

______________________________  _________________________  _________________
Signature of Person            Printed name                 Study Role    Date
Obtaining Consent

______________________________  _________________________  _________________
Printed name                 Study Role    Date

______________________________  _________________________  _________________

Appendix B. Intake Questionnaire

INTAKE QUESTIONNAIRE
Auditory Function and Cognition in Parkinson’s Disease, Feasibility Study

To be filled by a study team member: Participant for PD / CTRL _________

Please do not write your name on this form. If you have any questions, please do not hesitate to ask the study staff.

Year of Birth: ______________

Gender: Female / Male / Other (________)

PART 1: Disease Profile

Do you have any medical condition (other than Parkinson’s for PD)? YES / NO

If YES, Please list them: _______________________________________________________

If you are a control participant, you can skip to Part 2

How old were you when you were diagnosed with Parkinson’s disease (PD)? ______

How old were you when you started to experience symptoms of PD? _______

PART 2: Hearing Profile

Do you have any concerns about your hearing? YES / NO

If “yes”, how long have you been concerned for your hearing? _____________

Do you have any immediate family member (like parents or siblings) who experienced hearing problems since they were young? YES / NO

Please check the item(s) that applies to you:

<table>
<thead>
<tr>
<th>Types of noise exposure:</th>
<th># of yrs of exposure</th>
<th>Always wore hearing protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loud music (e.g., DJ, concert/band)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Loud equipment (e.g., motorcycle, chainsaw, lawn mower, forklift)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Use of guns (e.g., military, hunting)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Scuba diving</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Others (e.g., exposure to situations when hearing protection was recommended)

Have you experienced any of the following:

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>Description/Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear or head surgery?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head trauma or concussion?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness or imbalance issues?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear pain or discomfort?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear infections as a child?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear infections as an adult?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge from the ears?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudden hearing loss (&lt;90 days)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinnitus (ringing/buzzing)?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Have you taken any of the following in the past?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large doses of aspirin or ibuprofen (8-12 pills a day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large doses or extended uses of nonsteroidal anti-inflammatory drugs (NSAIDs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aminoglycosidic antibiotics (ex. UTI, abdominal infection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemotherapy drugs (ex. Cisplatin, carboplatin)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loop diuretics (ex. Renal disease, kidney failure)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PART 3: Amplification

Do you wear hearing aids? YES / NO

**If NO, you can stop the questionnaire.**

If YES, please continue to answer the following questions:

I wear hearing aid in ONE / TWO ear(s).

How often do you wear your hearing aids?

_____ hours per day OR _____ times a week / month OR only in specific situations:

_________________________________________

How long have you been using a hearing aid? _____________________
Appendix C. Correlations from the Linear Regression Analysis

Figure 4. A scatterplot of the relationship between hearing in noise (HINT) and age

Data points that fall within the red quadrant represent participants who reported poorer HINT scores that are 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the green quadrant represent participants who report HINT scores that are within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant ($N = 28$). HINT: hearing in noise test composite score.

$y = 0.0568x - 7.9281$

$R^2 = 0.1661$
Figure 5. A scatterplot of the relationship between hearing in noise (HINT) and the number of years since the onset of PD.

Note. Data points that fall within the red quadrant represent participants who reported a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the green quadrant represent participants who reported a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). HINT: hearing in noise test composite score.
Figure 6. A scatterplot of the relationship between hearing in noise (HINT) and perceived hearing impairment (HHIE-S)

Note. Data points that fall within the red quadrant represent participants who reported hearing difficulty (HHIE-S > 8) and HINT scores that fall 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the yellow quadrants represent participants who either have no hearing difficulty and HINT scores that are 2 SD poorer than the norm (Vermiglio, 2008), or reported having hearing difficulty (HHIE-S > 8) and HINT scores within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the green quadrant represent participants who report both no hearing difficulty and HINT score that is within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). HHIE-S: screening version of the hearing handicap for the elderly; HINT: hearing in noise test composite score.
Figure 7. A scatterplot of the relationship between hearing in noise (HINT) and objective hearing (PTA Worse)

Note. Data points that fall within the red quadrant represent participants who reported worse-than-normal hearing (PTA > 25 dB HL) in the worse-hearing ear and HINT scores that are 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the yellow quadrants represent participants who either have within-normal hearing (PTA ≤ 25 dB HL) and HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having worse-than-normal hearing (PTA > 25 dB HL) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the green quadrant represent participants who report both within-normal hearing (PTA ≤ 25 dB HL) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). HINT: hearing in noise test composite score; PTA Worse: pure-tone average of the worse-hearing ear.
Figure 8. A scatterplot of the relationship between hearing in noise (HINT) and state anxiety

Note. Data points that fall within the upper right (red) quadrant represent participants who reported having clinical level of state anxiety (STAI-S ≥ 39; Rutten et al., 2017) and HINT composite scores 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper left (yellow) and bottom right (yellow) quadrants represent participants who either reported having state anxiety below the cut-off and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having clinical level of state anxiety and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom left (green) quadrant represent participants who reported having state anxiety below the cut-off and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). STAI: state-trait anxiety inventory; HINT: hearing in noise test composite score.
Figure 9. A scatterplot of the relationship between hearing in noise (HINT) and trait anxiety

Note. Data points that fall within the upper right (red) quadrant represent participants who reported having clinical level of trait anxiety (STAI-T ≥ 42; Hanna & Cronin-Golomb, 2012) and HINT scores 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper left (yellow) and bottom right (yellow) quadrants represent participants who either reported having trait anxiety below the cut-off and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having a clinical level of trait anxiety and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom left (green) quadrant represent participants who report having trait anxiety below the cut-off and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). STAI: state-trait anxiety inventory; HINT: hearing in noise test composite score.

\[ y = 0.0155x - 4.7722 \]

\[ R^2 = 0.0149 \]
Figure 10. A scatterplot of the relationship between hearing in noise (HINT) and physical functioning

Note. Data points that fall within the upper left (red) quadrant represent participants who reported physical functioning that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience physical functioning within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having physical functioning 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both physical functioning and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.
Figure 11. A scatterplot of the relationship between hearing in noise (HINT) and role limitation due to physical functioning

Note. Data points that fall within the upper left (red) quadrant represent participants who reported role limitation due to physical health that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience role limitation due to physical health within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having role limitation due to physical health 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both role limitation due to physical health and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.
Figure 12. A scatterplot of the relationship between hearing in noise (HINT) and emotional health

Note. Data points that fall within the upper left (red) quadrant represent participants who reported emotional health that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience emotional health within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having emotional health 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both emotional health and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.

\[ y = -0.0118x - 3.3448 \]

\[ R^2 = 0.0173 \]
Figure 13. A scatterplot of the relationship between hearing in noise (HINT) and role limitation due to emotional health

Note. Data points that fall within the upper left (red) quadrant represent participants who reported role limitation due to emotional problems that is $2 \, SD$ poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is $2 \, SD$ poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience role limitation due to emotional problems within $2 \, SD$ of the Canadian population average (Hopman et al., 2000) and have a HINT score that is $2 \, SD$ poorer than the norm (Vermiglio, 2008), or reported having role limitation due to emotional problems $2 \, SD$ worse than the average (Hopman et al., 2000) and a HINT score that is within $2 \, SD$ of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both role limitation due to emotional problems and a HINT score that are within $2 \, SD$ of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant ($N = 28$). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.
Figure 14. A scatterplot of the relationship between hearing in noise (HINT) and energy

Note. Data points that fall within the upper left (red) quadrant represent participants who reported energy that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience energy within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having energy 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both energy and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.
Figure 15. A scatterplot of the relationship between hearing in noise (HINT) and social functioning

Note. Data points that fall within the upper left (red) quadrant represent participants who reported social functioning that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience social functioning within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having social functioning 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both social functioning and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.
Figure 16. A scatterplot of the relationship between hearing in noise (HINT) and pain

Note. Data points that fall within the upper left (red) quadrant represent participants who reported pain that is 2 SD poorer than the Canadian population average (Hopman et al., 2000) and a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008). Data points that fall within the upper right (yellow) and bottom left (yellow) quadrants represent participants who either experience pain within 2 SD of the Canadian population average (Hopman et al., 2000) and have a HINT score that is 2 SD poorer than the norm (Vermiglio, 2008), or reported having pain 2 SD worse than the average (Hopman et al., 2000) and a HINT score that is within 2 SD of the norm (Vermiglio, 2008). Data points that fall within the bottom right (green) quadrant represent participants who report having both pain and a HINT score that are within 2 SD of the mean. Trend line is the linear relationship between the variables. Each data point corresponds to one participant (N = 28). SF-36: RAND’s 36-item short-form health survey of subjective quality of health; HINT: hearing in noise test composite score.