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Faculty of Humanities
Department of Speech-Language Pathology and Audiology

Temporal resolution and speech perception in noise of adults with and without HIV with normal audiometric results

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Plagiarism declaration

I, Michaela Juliana Wantenaar, hereby declare that this dissertation is my own work. Where secondary material is used, it has been carefully acknowledged and referenced in accordance with the University of Pretoria Department of Speech-Language Pathology and Audiology's requirements.

I understand what plagiarism is and am aware of the University of Pretoria's policy regarding this matter.

Michaela J. Wantenaar

2019-11-23

Date of declaration

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List of abbreviations and acronyms

AFT-R	Auditory Fusion Test- Revised
AIDS	Acquired Immune Deficiency Syndrome
ART	Antiretroviral
CAP	Central auditory processing
CANS	Central auditory nervous system
CD4	Cluster of differentiation 4
CNS	Central nervous system
dB	Decibel
DIN	Digits-in-Noise
GDTh	Gap detection threshold
GIN	Gaps-in-Noise
HIV	Human Immunodeficiency Virus
HIV+	HIV positive
HIV-	HIV negative
Hz	Frequency
ID	Infectious disease
Ms	Millisecond
OHCHR	Office of the High Commissioner for Human Rights
RGDT	Random Gap Detection Test
RGDTh	Approximate Random Gap Detection threshold
RGDT_Th	Random Gap Detection threshold
SBAH	Steve Biko Academic Hospital
SD	Standard Deviation
SL	Sensation Level
SNR	Signal-to-noise ratio
SPPS	Statistical Package for Social Sciences
UNAIDS	Joint United Nations Programme on HIV and AIDS
WHO	World Health Organisation

Abstract

The Human Immunodeficiency Virus (HIV) epidemic is now in its third decade and it is growing to be one of the greatest health challenges the world has to face. At the end of 2018, the UNAIDS estimated that there were about 37.9 million people globally infected with HIV and AIDS. It was also estimated in 2018 that 7.7 million members of the South African population were HIV+. A disorder of the auditory system, such as a hearing loss, is one of the many effects that the HIV virus may have on the human body. Furthermore, central nervous system (CNS) damage can be a devastating consequence of HIV infection. The majority of research that was done regarding hearing in individuals with HIV has focused on peripheral hearing loss, with limited research reporting on auditory processing.

The main aim of this study was to determine the temporal resolution abilities and speech-in-noise perception of adults with HIV with normal audiometric results (audiograms) and to compare the findings to those obtained from healthy age and gender matched controls without HIV. A descriptive, cross-sectional comparative research design was utilized in this research study. Purposive convenience sampling was used to recruit participants with and without HIV**.**

This research study consisted of an HIV+ group (n=20) and an age and gender matched HIV- control group (n=20). All the participants in this study were in the age range of 18 to 40 years, had already been diagnosed as HIV negative or positive, and had audiometric and acoustic immittance test results that could be classified as normal.

The procedures used for data gathering consisted of auditory processing tests including the Digits-In-Noise Test (DIN), the Gaps-In-Noise Test (GIN), and the Random Gap Detection Test (RGDT). The two groups of participants were compared based on the results of the auditory processing tests.

The results for the RGDT regarding the mean gap detection threshold indicated a statistically significant difference ($p<0.001$) between the HIV and control group at all test frequencies. A statistically significant difference ($p<0.001$) was obtained for the total percentage correct scores as well as the mean gap detection threshold between the two groups for the GIN test. Finally, a statistically significant difference was found between the two groups when speech-in-noise abilities was measured through the DIN test.

This study provided more information on the effects of HIV on speech perception in noise, auditory information processing and more explicitly on temporal resolution. Evidence of the present study suggests a strong association between HIV and temporal resolution abilities. If individuals that are HIV+ present with temporal resolution deficits it could lead to speech-in-noise difficulties, as this processing ability is a precondition for comprehending speech in background noise as well as in quiet, as speech sounds fluctuate over time.

Keywords

Auditory processing, Digits-In-Noise (DIN) test, gap detection threshold, Gaps-In-Noise (GIN) test, Human Immunodeficiency Virus, Random Gap Detection Test (RGDT), speech perception in noise, temporal resolution.

Chapter 1
Introduction

The Human Immunodeficiency Virus (HIV) epidemic is now in its third decade and it is proving to be one of the greatest health challenges the world has to face. At the end of 2018, the UNAIDS estimated that there were about 37.9 million people globally infected with HIV and AIDS. Of these numbers, 1.7 million were children younger than 15 years of age. It was also estimated in 2018 that 7.7 million members of the South African population were living with HIV and AIDS, with the prevalence rate of adults between the ages of 18 to 49 years of age at about 20.4% (UNAIDS, 2019).

Infection with HIV leads to the advancement of Acquired Immunodeficiency Syndrome (AIDS) (HIV.gov, 2017). HIV is a virus that invades the body's immune system by infecting the CD4 cells (also known as T cells). It infects the body and destroys these cells that adapt the functioning of the immune system, leading to the exhaustion of bodily defences and advancing the occurrence of an array of diseases labelled opportunistic infections (Quidicomo & Matas, 2013).

The high prevalence of HIV has also placed a heavy burden on the provision of audiological healthcare services in South Africa (Swanepoel, 2006), due to the fact that the precise occurrence and mechanisms of auditory dysfunction create difficulties in the assessment, monitoring and treatment of individuals (Kallail, Downs, & Scherz, 2008). This was also described in a policy document compiled by the World Health Organization (WHO), Joint United Nations Programme on HIV and AIDS (UNAIDS) and the Office of the High Commissioner for Human Rights (OHCHR) where the relationship between disability and HIV was described and the inadequate attention that HIV-related disability has received was stressed (UNAIDS, WHO, & UNOHCHR, 2009). In this document it is recognised that individuals living with HIV are at an increased risk of developing disabilities and impairments due to the virus itself, as well as to the side effects of specific treatments (UNAIDS, WHO, & UNOHCHR, 2009). Past research and discussions focussed mostly on the mortality rate due to HIV (UNAIDS, WHO, & UNOHCHR, 2009). It is essential, however, to also consider the impact that this virus has on the national costs of medical care, and the implications for society, such as the probable loss of a productive work force as well as the quality of life of these individuals (UNAIDS, WHO, & UNOHCHR, 2009).

The term “quality of life” can refer to the experience a person has of his or her own life as well as to the person’s actual living conditions. With reference to people living with HIV and AIDS, quality of life has been defined as the awareness of an individual when it comes to his/her position in life (Wig, Lekshmi, Hemraj, Ahuja, Mittal, & Agarwal, 2006). This awareness falls within the cultural systems where individuals live, and it relates to their expectations, goals, concerns and standards (Wig et al., 2006). HIV has a negative impact on the psychosocial, spiritual, and emotional well-being of an individual. Furthermore, this virus has possible biomedical consequences including disorders of the auditory system, which may lead to an overall decrease in quality of life (Mngadi, 2003). A disorder of the auditory system, such as a hearing loss, is only one of the many effects that the HIV virus may have on the human body. Central nervous system (CNS) damage can be a devastating consequence of HIV infection, with a major impact on quality of life (Zhan, Fellows, Qi, Clavier, Soli, Shi et al., 2018). This highlights the importance of early treatment by healthcare professionals to avert and decrease the detrimental effects that this virus has on the individual and his/her quality of life.

The HIV virus may influence various aspects of the auditory system, and the effects can be divided into three main groups. Firstly, hearing can be directly affected by the HIV virus, as it can affect the peripheral and central neural pathways involved in hearing (Maro, Moshi, Clavier, MacKenzie, Kline-Schroder, Wilbur et al., 2014). Secondly, it may indirectly affect the auditory system through the development of infections such as otitis media, which can cause a conductive hearing loss. Otitis media is common amongst individuals with HIV due to the immunocompromised state leading to more infections (Maro et al., 2014). Finally, it may cause a sensorineural hearing loss, mainly because of the potentially ototoxic medications which are used for treatment of other life-threating infections such as anti-tuberculous or anti-retroviral medication (Maro et al., 2014).

Based on the magnetic resonance imaging (MRI) findings in a study by Zhan et al. (2017), it is reasonable to assume that individuals with HIV could possibly have central auditory processing (CAP) deficits. Since HIV infection can damage central auditory pathways, central auditory tests could be useful to track or diagnose central nervous system effects of HIV. Furthermore, it is possible that CAP deficits will correlate to the cognitive deficits in HIV+ patients, which means that central auditory tests may provide

a new way to assess CNS function in HIV+ individuals (Zhan et al., 2017). Maro et al. (2014) found that although HIV+ individuals present with normal peripheral hearing, they may at the same time present with signs of central auditory processing deficits. Further extensive research proposes that not only does HIV affect peripheral hearing, but that HIV+ individuals have been shown to struggle to comprehend speech-in-noise (Luque, Orlando, Leong, Allen, Guido, Yang, & Wu, 2014). Speech perception in noise is a cognitively challenging task which links to central auditory processing. Torre and colleagues (2016) investigated the speech audiometric results of HIV+ and HIV- individuals, by comparing various speech audiometric measures for the two groups of participants. However, since the tests were conducted in a quiet environment with a moderately increased presentation level, they caused a ceiling effect and proved to be too easy for the participants. A more complex listening task should be presented to provide a better clinical perspective on the evaluation of the effect that HIV has on speech communication. It is recommended that such complex listening tasks should include speech-in-noise testing such as digits-in-noise testing, BKB sentences or Quicksin.

An essential skill of auditory processing, linked to speech perception in noise, is temporal processing, which is the awareness of sound in a constrained or definite interval field (Geffner & Ross-Swain, 2007). This processing ability is a precondition for comprehending speech in background noise as well as in quiet conditions, as speech sounds fluctuate over time. Temporal processing can be divided into four aspects, namely temporal ordering, temporal integration, temporal masking, and temporal resolution (Geffner & Ross-Swain, 2007). Of importance for the current research project is temporal resolution, which denotes a temporal processing task used in the comprehension of quick altering acoustic signals and is essential for defining momentary changes in the intensity of background noise, a skill that is of vital importance for speech acoustic perception. Temporal resolution affects the awareness of temporal features of speech as well as breaks, awareness that helps individuals to differentiate amongst speech sounds (Vaidyanath & Yathiraj, 2015).

Previous studies have shown a link between the perception of speech-in-noise and temporal resolution deficits (determined by gap detection in the older population) as well as gap detection thresholds (Harris, Eckert, Ahlstrom, & Dubno, 2010).

It is possible that the hearing deficits experienced by HIV+ individuals, such as having difficulty with the comprehension of speech (Maro et al., 2014), could be an indication of central auditory involvement. This could be evidence of the neurocognitive side effects due to continuous infection and inflammation of HIV. In summary, an existing study (Torre, Hoffman, Springer, Cox, Young, Margolick, & Plankey, 2016) proposed that auditory problems experienced by HIV+ individuals may be a consequence of central auditory processing difficulties, but should be investigated.

In order for hearing care professionals to appropriately evaluate, treat, manage, and monitor HIV+ individuals, an increasing amount of evidence-based information is needed on the occurrence and mechanisms of auditory dysfunction in these specific individuals. Further research should focus on the processes of auditory neural functioning and central auditory processing, and should include speech perception in noise tests. More complex listening tasks should be conducted as there is limited research relating to speech perception and speech-in-noise abilities of HIV+ individuals (Torre et al., 2016). Most research regarding hearing functions of HIV+ individuals has focused on peripheral hearing loss, with limited research reporting on auditory processing. Even though research evidence of central auditory deficits has been described, most of the previous research did not focus on a specific auditory processing skill but rather on the integrity of the auditory pathway (Dawood, Klop, Olivier, Elliott, & Pillay, 2019). The aim of the current study is therefore to determine the temporal resolution skills and speech perception in noise of adults with and without HIV.

Chapter 2
Methodology

2.1 Introduction

In this chapter the research aim is introduced and the research procedures as well as the ethical considerations that were applied throughout the entire research process are described. The procedures used for participant selection and data collection, apparatus and materials used, as well as the methods implemented for statistical analyses are also discussed

2.2 Research aim

The main aim of this study was to determine the temporal resolution abilities and speech-in-noise perception of HIV+ adults with normal audiometric results (audiograms) and to compare the findings to those obtained from healthy age and gender matched HIV- controls.

2.4 Research design

A descriptive, cross-sectional comparative research design with a quantitative approach was used in this study. A cross-sectional design was followed as data was collected at a single point in time, comparing two groups (Maxwell & Satake, 2006). The comparative design enabled the researcher to compare the auditory processing test results of a control and an HIV group. As the study involved numerical data a quantitative approach was followed. It aimed to identify relationships among certain variables and depending on the results that was obtained to either modify or confirm current theories (Leedy & Ormrod, 2015).

2.5 Ethical considerations

Whenever human beings are the focus of a study, ethical issues have to be considered meticulously (Leedy & Ormrod, 2015). Ethical approval for this research was obtained from the Departmental Research and Ethics Committee and the Research and Ethics Committee of the Faculty of Health Sciences (Appendix A) at the University of Pretoria. The following ethical considerations were taken into account in this study:

2.5.1 Permission from the relevant authorities

The Chief Executive Officer (CEO) of Steve Biko Academic Hospital (SBAH) granted permission to conduct the research study at the hospital (Appendix B) and to access

records and files of the patients (Appendix B). Permission to use HIV patients as participants for this study was obtained from the Head of the Infectious Disease (ID) Clinic at SBAH (Appendix C). Additionally, permission was obtained by the Audiology Department of SBAH to test the participants (Appendix D).

2.5.2 Protection from harm

The participants were not exposed to any physical or psychological harm during their participation. The audiological testing did not pose any greater risks than typical day to day risks. Participants who took part in this study were not exposed to unusual embarrassment, loss of self-esteem, or stress (Leedy & Ormrod, 2015). The only risk related to participation in this study was that a participant could obtain information pertaining to their HIV status that they were not aware of i.e. an HIV positive result. If an unanticipated HIV positive result was obtained, counselling was available at all the respective clinics where testing was done. The current study complied to the standards set in the Declaration of Helsinki (Appendix E).

2.5.3 Informed consent

All participants were provided with comprehensive information regarding the study and had the right to decide whether they wished to participate in the study or not. Sufficient opportunity for asking questions was given to each participant before the study commenced, as well as during the study (Leedy & Ormrod, 2015). Assurance was given to the participants that they could withdraw at any stage, should they wish to do so, without any negative consequences (Leedy & Ormrod, 2015). Participants were informed of the nature of the study by a letter requesting informed consent to participate in the study (Appendix F & G). The letter of informed consent contained the following information:

- An explanation of the study and what participation involved, with regard to the duration of testing and what to expect during the gathering of data.
- An indication that participation was voluntary and that the participant could withdraw at any given time without any negative consequences.
- The assurance that all responses would be treated in a confidential manner.
- A declaration of the participant that by giving informed consent they allowed the researcher to obtain any information needed from their medical history, including their HIV status and CD4 cell count.

- Contact details of the study supervisor and the researcher should the participants have concerns or questions.

Participants received a letter requesting informed consent to undergo an HIV test. This letter included procedures of the test, advantages and disadvantages of knowing your status as well as the potentials risks and discomforts (Appendix H). To ensure that personal information and the identity of every participant were kept confidential, each participant was allocated a numerical code i.e. A01.

2.5.4 Honesty

According to Leedy and Ormrod (2015) the results of any study should be described in an honest way without misleading participants about the nature of the results. The test results were readily available to each participant to view and explained to each participant after testing.

2.5.5 Data storage

As determined by the University of Pretoria, data must be securely stored for a minimum of 15 years. Data will be stored in hard copy and electronically and will be archived at the University of Pretoria, at the Department of Speech-Language Pathology and Audiology (Appendix I). No identifying information of the participants was included in these files.

2.5.6 Plagiarism

A declaration regarding plagiarism which has been signed by the researcher can be found in Appendix J. The study is the researcher's own original work. All secondary material was referenced and acknowledged according to the APA 6th Edition referencing guidelines. Data were not changed for the purpose of confirming a satisfying conclusion (Leedy & Ormrod, 2015).

2.5.7 Confidentiality

Personal information and results from participants were kept strictly confidential during the data analysis and reporting processes of this study. An alpha-numeric code (e.g. A01) was allocated to each participant after which all personal identifiers were removed.

2.5.8 Referrals

Once data collection commenced, if any otologic complaint, hearing loss, or auditory processing difficulties was noted in a participant, the participant received contact

information of a relevant health professional for further managing and testing of their complaint (Appendix K). All the participants who required further management were given informational counselling regarding the importance of consulting the relevant health professionals for the management of their condition.

2.6 Participants

The following section describes the research context and the sampling method as well as the criteria for the selection of participants, the description of the participants in this study, and the procedure for the selection of participants.

2.6.1 Research context

Participants in the HIV+ group were sampled from the ID Clinic at SBAH and data collection took place at the Audiology Department of SBAH (Appendix D). The participants in the HIV- group were recruited through convenience and randomized sampling at a healthcare clinic. Only participants who had attended voluntary HIV screening at a healthcare clinic on their own accord were recruited. The data collection was done at the Department of Speech-Language Pathology and Audiology, University of Pretoria.

2.6.2 Sampling method

Participants were selected using purposive convenience sampling. In purposive sampling, participants are chosen with a particular purpose in mind (Leedy & Ormrod, 2015; Strydom & Venter, 2002). Participants of the HIV+ group were chosen purposively from the ID clinic at SBAH, according to specific criteria including age, HIV status, and hearing status. The participants of the HIV- group were collected through convenience and randomized sampling at healthcare clinics where they had undergone voluntary HIV screenings on their own accord. Convenience sampling was used as only participants that were readily available were used in this study (Leedy & Ormrod, 2015).

2.6.3 Participant selection criteria

Forty participants were selected for participation in this research study, 20 in the HIV- (control) group and 20 in the HIV+ group.

The following criteria were set for both the HIV+ and HIV- (control) group:

- Participants between the ages of 18 to 40 years were chosen to participate in this research study. The reason for this specific age range was so that participants could provide legal consent (Strode, Slack, & Essack, 2010). The second reason was to avoid the presence of possible presbycusis, as well as age-related auditory processing problems. Presbycusis is known to affect older individuals as the stria vascularis, inner and outer hair cells in the cochlea and neural fibres can be influenced by the aging process (Ferrite & Santana, 2005). Furthermore, age-related changes can also result in a deterioration of temporal processing abilities. Previous studies have indicated a link between temporal resolution deficits as determined by gap detection in the older population and the perception of speech-in-noise (Harris et al., 2010). Auditory processing abilities slowly begin to deteriorate in middle-aged individuals (approximately 40-60 years) (Sanju, Bohra, & Sinha, 2016).
- Furthermore, participants had to be proficient in English in order to read and understand the questions that were asked in the informal interview, as well for understanding the test instructions. Another reason was that the majority of the tests were conducted in English and this required the participants to understand and speak English.
- Normal peripheral hearing is a prerequisite for central auditory testing, as test results can be influenced by a peripheral hearing loss (American Academy of Audiology, 2008). It was thus of the utmost importance that participants presented with normal pure tone thresholds, i.e. equal to or less than 15 dB HL at octave intervals from 125 to 8000 Hz (Northern & Downs, 2014).
- In addition, participants' acoustic immittance test results had to be normal. The participants had to present with a type A tympanogram bilaterally with middle ear pressure at -100 to 50 daPa, static compliance of 0.3 to 1.7 ml and the ear canal volume had to be 0.9 to 2.0 ml (Martin & Clark, 2006). Acoustic reflex thresholds had to be present at 1000 Hz and range from 70 to 95 dB HL (Kramer, 2014).

The control group consisted of 20 voluntary participants. The participant of this group were gender and age matched to the HIV+ group and had to adhere to the following criteria:

- The participants had to be HIV negative. To confirm that these participants were HIV negative, they had to undergo an HIV screening test. These participants could be screened at their local clinic such as the DisChem Clinic, their preferred physician or at an alternate clinic of their choice. The costs of the screening test were covered by the researcher. Proof of the aforementioned screening had to be presented to the researcher before testing could commence. In the event that the HIV screening test indicated a positive result, the facility/ clinic staff who had administered the test provided counselling. If this participant still wished to participate, he/she was assigned as a participant to the HIV group. If, however a participant declined to know their HIV status, they were excluded from the study without any negative consequences. However, in this current study none of the screening tests undergone by the participants indicated a positive result.

The HIV group consisted of 20 HIV+ participants. For these participants to be included in the study they had to be HIV positive. Their HIV diagnosis had to be confirmed by the medical staff at the ID Clinic at SBAH. Hospital files were used to gather information regarding their CD4 cell counts. Information had to be provided on the use of ART's, due to the variety of treatments that the participants may receive, some of which may be ototoxic.

The exclusion criteria for both the HIV+ and HIV- (control) group included several factors:

- On the day of testing, participants had to present with normal peripheral hearing as the presence of a hearing loss could affect the processing of sound, which in turn could possibly have affected speech understanding in background noise (Glyde, Hickson, Cameron, & Dillon, 2011).
- Participants should not have been exposed to loud noise as one of the major types of adult-onset hearing loss is noise-induced hearing loss (Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005). Hair cells in the cochlea are damaged due to chronic noise exposure and metabolic changes caused by hypoxia (insufficient oxygen supply to tissues and organs of the body) resulting from noise induced capillary vasoconstriction (Ferrite & Santana, 2005). Therefore, participants with a history of noise exposure were excluded from the study.

2.6.4 Material and apparatus for participant selection

Specific materials and apparatus were used to ensure that participants met the necessary inclusion criteria (Table 1).

Table 1. Material and apparatus for participant selection

Material and apparatus	Rationale
Grason Stadler (GSI) Tympstar	Tympanometry and ipsilateral reflex measurements were performed using this device. This device was calibrated in March 2018.
Interacoustics AT235h audiometer / WelchAllyn GSI 61 clinical audiometer	This item of equipment is a diagnostic two channel audiometer. Pure tone air conduction thresholds (through headphones) were obtained with this audiometer to determine the participant's thresholds at 125 Hz – 8000 Hz and their degree of hearing. The Interacoustics AT235h audiometer was calibrated in March 2018.
Record form	The data in the hospital files of the participants in the HIV+ group were reviewed in order to ensure that the participants met the inclusion criteria. The following information was collected: age, gender, duration of HIV, CD4 cell count and current medication (Appendix M).
Interview schedule	Information that was not stated in the patients' files was obtained by means of an informal interview (Appendix L). Specific information was obtained such as noise exposure, physical trauma, surgery, and family history with regard to their hearing.

2.6.5 Procedure for participant selection

Figure 1 presents an outline of the procedures that were performed in order to select the participants, and is followed by a detailed description of the various aspects.

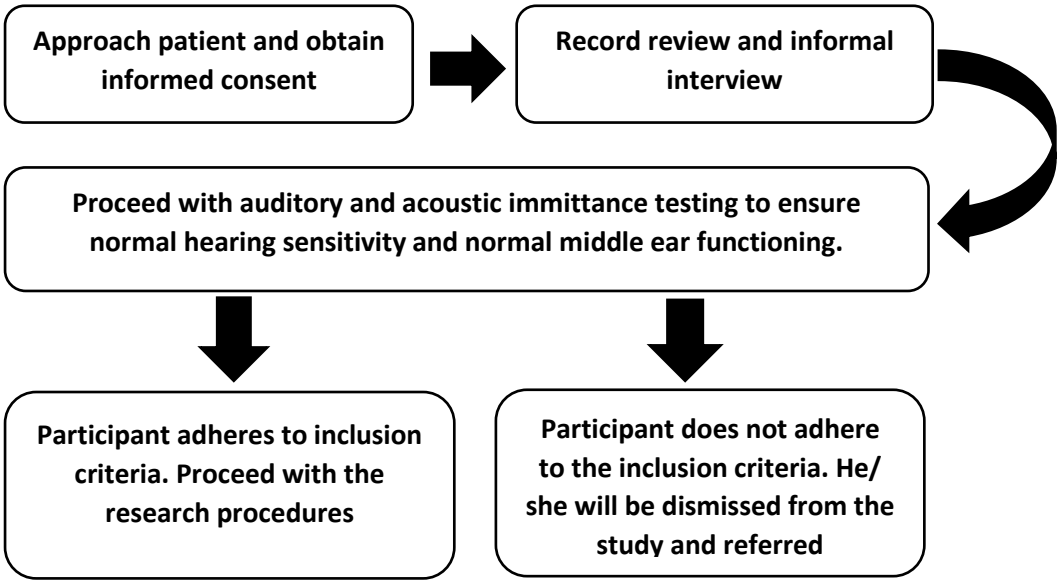

Figure 1: Participant selection procedure

Only after participants had been contacted and had signed the informed consent (Appendices F, G & H) were they be able to participate in this study. An informal interview, (Appendix L) as well as a review of the files of the HIV+ participants was conducted. Audiological selection procedures for both the HIV- and HIV+ group commenced, which included pure tone audiometry and acoustic immittance measurements. These tests were conducted at the Audiology Department of SBAH and at the Department of Speech-Language Pathology and Audiology at the University of Pretoria. The following procedures were used:

- **Acoustic immittance measurements**

These measurements were done to confirm normal middle ear functioning of the participants in this study.

- Tympanometry

  A soft probe was inserted into the ear canal to measure middle ear functioning. The participants were informed that they would feel varying pressure in the ear. It was not necessary for the participant to respond in any way but they were requested to sit in an upright position and not talk, chew, or cough while the probe was in their ear. Normal results were documented in terms of compliance (0.3 to1.7 ml), ear canal volume (0.9 to 2.0ml), and middle ear pressure (-100 to 50 daPa) (Martin & Clark, 2006). Results outside of the normal limits as stated by Martin and Clark (2006) were classified as abnormal and recorded according to type. If participants presented with a possible middle ear pathology the correct referrals were made to an Ear, Nose and Throat specialist and they were not included in the study.

- Acoustic reflex measurements

  The acoustic reflex (stapedius reflex) can be described as the spontaneous muscle contraction of the middle ear muscles in reaction to high intensity sounds (Clark, 2018). The same equipment as for tympanometry was used for this test. The probe was not removed from the ear of the participant and acoustic reflexes were measured using the same equipment. A single reflex at 1000 Hz was elicited for screening purposes. For reflexes to be considered as normal, ipsilateral reflexes had to be present at 1000 Hz and range between 70 and 95 dBHL

(Kramer, 2014). Results were considered abnormal if the reflex was elicited at a lower level than 70 dB above threshold or a higher level than 100 dB above threshold. Therefore, the classification was normal, abnormal, or absent. If participants presented abnormal or absent reflexes, the correct referrals were made to an Ear, Nose and Throat specialist and they were not included in the study

- **Pure tone audiometry**

Pure tone audiometry aimed to evaluate the participants' hearing sensitivity across a frequency range of 125 to 8000 Hz. The participants were seated in a soundproof booth and they had to press a button when they heard a sound presented through earphones to test air-conduction thresholds. Participants had to have pure tone thresholds at all frequencies between 0 and 15 dB to be included in the study. If participants presented with a hearing loss, it was described in accordance with the degree of the loss i.e. slight hearing loss, mild hearing loss, moderate hearing loss, severe or profound hearing loss (Stach, 2010). These participants were referred to an audiologist for further intervention and excluded from the study.

2.6.6 Description of participants

The participants involved in the current study are described according to their demographic features.

- Study population

A total of 40 adults participated in the study, and this population comprised of two groups. The first group consisted of 20 HIV+ participants and the second group of 20 HIV- controls. Table 2 displays the demographic features of both groups of participants.

Table 2. Demographic features of both groups of participants

	All (n=40)	**HIV+ group (n=20)**	**HIV- group (n=20)**	***P value***
Age (Years)	29.18 (±7.2)	29.45 (±7.7)	28.90 (±6.9)	0.583
Gender (%)				
Male	14 (35%)	7 (35%)	7 (35%)	-
Female	26 (65%)	13 (65%)	13 (65%)	-

± = Standard Deviation, %= Percentage, *$p \leq 0.05$ statistically significant.

The mean age of the two groups was very similar (HIV+ group: 29.4 years, ±7.7, range 20 to 40; control group: 28.9 years, ±6.9, range 20 to 39) with no statistically significant

difference between the two study groups (p=0.583; Independent Sample T test). The researcher allowed a two-year age difference between the age of the HIV+ participants and their age-matched HIV- participants, due to the difficulty in finding exact age matches between the HIV+ and HIV- group. An equal number of male and female participants was tested for both groups, 14 males (35%) and 26 females (65%).

2.7 Data collection

Data collection involved the use of certain materials and apparatus and the administration of specific procedures.

2.7.1 Material and apparatus for data collection

The Interacoustics AT235h and WelchAllyn GSI 61 clinical audiometer (calibrated in March 2019), the Sansui CD210 CD player and Telephonic -50 earphones were used for the Gaps-In-Noise (GIN) test and Random Gap Detection Test (RGDT). For the Digits-In-Noise (DIN), a Samsung phone with telephonic -50 earphones were used. Temporal resolution abilities were evaluated using the Random Gap Detection Test (RGDT), and the Gaps-In-Noise (GIN) test. The Digits-In-Noise (DIN) test evaluated the speech perception in noise abilities.

- **Random Gap Detection Test (RGDT)**

This test evaluated temporal resolution abilities, which can be defined as the capacity of the auditory system to react to rapid changes of sound over time. Gap detection paradigms measure an important facet of this ability (Owens, Campbell, Liddell, DePlacido, & Wolters, 2007). The purpose of these paradigms was to examine the shortest time interval a listener could detect, either at the level of the brainstem or cortically. The RGDT was developed by Robert Keith and is a modified form of the Auditory Fusion Test Revised (AFT-R) (Chermak & Lee, 2005). The RGDT seeks to measure the gap detection threshold, using randomised inter-pulse intervals with both click and tonal stimuli. Owens and colleagues (2018) conducted a study to identify age-related effects on temporal resolution ability, as measured by the RGDT. As older adults frequently perform poorly on tasks of speech understanding in noisy listening conditions, it has been suggested that deficits in temporal resolution may be responsible for this difficulty. The RGDT consists of a binaural presentation of a gap set in pure tone stimulus pairs, at frequencies 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The gaps randomly increase and decrease in duration, changing from 0 to 2, 5, 10, 15,

20, 25, 30 and 40 ms intervals (Chermak & Lee, 2005). There are four subsets in the RGDT. Subsets 1 and 3 are practice subsets presenting ascending inter-pulse intervals. Subset 2 and 4 (actual tonal or click subsets) randomly present inter-pulse intervals (Chermak & Lee, 2005). Subset 1 includes nine 500 Hz tone pairs presented in ascending inter-pulse intervals. Subset 2 presents nine randomized tone pairs for four frequencies namely 500, 1000, 2000 and 4000 Hz. Subset 3 consists of nine click pairs with ascending inter-pulse intervals. Lastly, subset 4 presents click pairs divided by nine randomized inter-pulse intervals (Chermak & Lee, 2005).

- **Gaps-In-Noise (GIN) test**

The GIN test was developed by Frank Musiek and his associates to measure temporal resolution abilities (Paulovicks, 2008). Musiek and colleagues (2005) conducted a study to compare the gap duration threshold of listeners who presented with central auditory processing disorders to the gap duration threshold of a group of normal hearing listeners. The results showed that the gap duration thresholds were longer in the group who presented with a central auditory processing disorder. This group was compared to a normal hearing group who achieved mean gap duration thresholds of 4.8 and 4.9 ms in the left and right ear. In addition, the GIN displays sensitivity to central auditory system lesions (Chermak & Lee, 2005). Chermak and Lee (2005) described this procedure as a monaural presentation of zero to three gap sets in six second intervals of white noise at 55 dB SL, with a duration of 2 to 20 ms between the gaps. Throughout the test, 10 noise intervals vary for a total of 60 gaps presented in each of the four alternative lists (Musiek, Shinn, Jirsa, Bamiou, Baran, & Zaida, 2005).

- **Digits-In-Noise (DIN) test**

The DIN test was developed as a diagnostic speech-in-noise hearing test to detect a hearing loss for speech recognition in noise (Potgieter, Swanepoel, Myburgh, Hopper, & Smits, 2016). This test measures the signal-to-noise ratio (SNR) where a listener will correctly identify 50% of the three digits presented correctly. All stimuli were presented binaurally. The first set of numbers that was presented were presented at this chosen intensity level. If the digit triplet was entered 100% correctly, the next stimulus was presented at a 2 dB lower SNR than the previous digit. When the digit triplet was typed in incorrectly the next stimulus was presented at a 2 dB higher SNR. Each test consisted of 23-digit triplets to estimate the SNR corresponding to the 50% correct

recognition probability (Swanepoel, Myburgh, Smits, & Potgieter, 2017). This test is useful, as it is an affordable and an accessible alternative available to developing countries to determine speech perception abilities in noise (Swanepoel, Myburgh, Smits, & Potgieter, 2017).

2.7.2 Procedures for data collection

Before data collection procedures commenced a pilot study was conducted. The pilot study will be described first followed by a detailed description of the research procedures for the main study.

Pilot study

- A small-scale trial run was done whereby the practicality and feasibility of the procedures, instructions, equipment, interpretation of results and the time efficiency of the data collection procedures were tested. Therefore, the pilot study assisted the researcher to make any changes with regard to the procedures before the main study commenced (Strydom, 2002). Five HIV negative participants were requested to read the informed consent letter (Appendix G & H) and partake in the interview (Appendix L). Feedback regarding the questions asked in the interview was encouraged, allowing the researcher to make the necessary changes. Furthermore, screening procedures including immittance testing and pure tone audiometry were conducted, followed by the GIN test, the RGDT and the DIN test, if the participants presented with normal hearing. The duration of the entire test procedure was 90 minutes. The participants gave feedback about the test procedures. The results showed satisfactory outcomes and no changes regarding the test procedures were deemed necessary.

The specific research procedures for each test entailed the following:

- For the procedure of the RDGT, the number of tones or clicks heard had to be counted by the listener, with options being one or two tones or clicks. The listener could give a verbal response or respond non-verbally by pointing to one or two dots or by raising one or two fingers (Chermak & Lee, 2005). Gap detection thresholds greater than 20 milliseconds were described as abnormal and a temporal processing disorder was deemed present (Keith, 2003).

- The GIN test was presented monaurally and the participants were instructed to push a response button as soon as they perceived a gap in between the noise. The shortest interval detected in four of the six presentations is known as the gap detection threshold, which can be used to identify central auditory nervous system lesions. Results obtained from the GIN were considered abnormal when the gap detection threshold exceeded 6 milliseconds and the calculated percentage (the number of correct responses) were less than 54%. This indicated the presence of a temporal processing disorder (Paulovicks, 2008).
- The DIN test was conducted by presenting three digits ranging from 0 to 9 in background noise, through headphones on a smart phone. Once the three digits had been presented, a screen popped up where the listener had to type what they heard. Even if it was not possible to identify all three numbers, they had to type in three numbers to be able to continue to the next one. Twenty-three, three digit stimuli were presented. Once the test had been completed, the results were depicted as a signal-to-noise ratio (SNR). Expected results were -8 SNR. A SNR lower than -8 was considered to be an abnormal test result, indicating that the listener possibly struggled to hear speech in the presence of background noise (Potgieter et al., 2016).

2.8 Data processing and analysis procedures

For the purpose of this study, data collection sheets were created in order to record all the test results from the participants in the HIV negative and HIV positive groups (Appendix M). By coding and editing data it was possible to analyse the data using the IBM Statistical Package for Social Sciences (SPSS version 22) statistical programme. The data were adapted into numerical format and stored on a Microsoft Excel sheet and introduced for analysis to the statistical programme and by applying a repeated measure analysis of various variables. Different statistical methods were used by the biostatistician (Appendix N) to analyse the data. This included descriptive statistics. Depending on the distribution of the data such as median, standard deviation, 25^{th} and 75^{th} percentiles, percentages and numbers were used to describe the data. Subsequently, to test for differences between two independent groups (e.g. different participants in the HIV- and HIV+ group), the Mann-Whitney test was used (Morgan, Leech, Gloeckner, & Barrett, 2013). A p-value of <0.05 was considered to be statistically significant. On the other hand, if the p-value was >0.05, the differences

between the groups were not considered to be statistically significant (Morgan, Leech, Gloeckner, & Barrett, 2013). Graphs, tables, and figures were used to deliver a more adequate way of depicting and representing the data.

2.9 Reliability and validity

Validity ensures accuracy in results (Maxwell & Satake, 2006) whereas reliability ensures consistency in the results (Leedy & Ormrod, 2015). The followings aspects ensured the reliability and validity of this study:

Reliability was ensured by using calibrated equipment. To ensure tester reliability all the tests that were conducted were performed by the researcher. The testing environment remained the same throughout the study and each participant underwent the same test battery. Furthermore, a pilot study was conducted to increase the reliability of the study.

Validity is an indication of the accuracy of a measurement and the degree to which it accurately represents the data that was intended to be measured (Maxwell & Satake, 2006). To ensure the validity standardised and validated measurements were used namely the Digits-In-Noise (DIN) test, Gaps-In-Noise (GIN) test and the Random Gap Detection Test (RGDT). Accurate results were also ensured by giving each participant clear instructions allowing them to understand the tests and the responses they had to give. Furthermore, adhering to the strict selection criteria for participant collection also warranted validity.

Chapter 3

Results

The results of temporal resolution and speech-in-noise tests were obtained from 20 HIV negative participants and were compared with the results obtained from 20 age and gender matched HIV positive participants. In this chapter the results of the RGDT indicating the gap detection thresholds for each group of participants are represented in table format. Furthermore, the results of the GIN test, specifically the total percentage of correct responses and the gap detection threshold, are also tabulated. Lastly, the DIN test results will also be presented in table format. Consequently, temporal resolution testing will be discussed first in terms of the RGDT followed by the discussion of the GIN test and lastly of the DIN test.

3.1 Comparison between male and female participants

The comparisons between male and female participants of both groups for each test appear in Tables 3 and 4.

Table 3. Comparison of male and female participants in the HIV- (control) group

Control group									
	Male (n=7)				Female (n=13)				p-value
	Min	Max	Mean	SD	Min	Max	Mean	SD	
DIN: SNR	-12.60	-10.00	-11.65	0.92	-12.20	-10.60	-11.44	0.56	0.354
GIN: GD Threshold Right ear (ms)	5	6	5.71	0.48	3	6	5.23	1.01	0.388
GIN: GD Threshold Left ear (ms)	5	6	5.43	0.53	4	6	5.38	0.76	1.000
GIN: Total score in %	63	75	67.57	4.75	61	85	69.69	7.45	0.740
RGDT: 500 Hz (ms)	2	10	5.29	2.36	2	15	6.69	3.49	0.429
RGDT: 1000 Hz (ms)	2	15	5.43	5.15	2	5	3.85	1.51	1.000
RGDT: 2000 Hz (ms)	2	10	7.00	3.87	0	10	5.46	3.52	0.414

RGDT: 4000 Hz (ms)	2	10	4.86	2.67	0	10	4.62	3.45	0.711
RGDT: Click (ms)	2	10	6.71	3.25	2	10	6.23	3.32	0.855

*$p \leq 0.05$ statistically significant

The results detailed in Table 3 reveal that there was no statistically significant difference between male and female participants for any of the tests. The comparison between male and female participants in the HIV+ group is depicted in Table 4.

Table 4. Comparison of male and female participants for HIV+ group

HIV+ group									
	Male (n=7)				Female (n=13)				p-value
	Min	Max	Mean	SD	Min	Max	Mean	SD	
DIN: SNR	-11.20	-9.20	-10.54	0.75	-12.20	-4.40	-10.12	2.05	0.804
GIN: GD Threshold Right ear (ms)	8	10	9.14	1.06	8	10	9.54	0.87	0.613
GIN: GD Threshold Left ear (ms)	8	12	10.00	1.63	8	12	9.69	1.10	0.722
GIN: Total score in %	34	53	44.71	6.67	39	49	44.54	3.282	0.954
RGDT: 500 Hz (ms)	5	20	10.00	5.77	10	30	17.69	6.95	0.026
RGDT: 1000 Hz (ms)	5	25	16.43	7.48	5	40	15.77	9.32	0.664
RGDT: 2000 Hz (ms)	5	40	17.14	11.12	5	30	16.92	7.51	0.604
RGDT: 4000 Hz (ms)	10	40	18.57	9.88	5	30	15.00	6.12	0.437
RGDT: Click (ms)	10	30	17.14	6.36	10	20	14.62	4.77	0.423

*$p \leq 0.05$ statistically significant

Table 4 indicates that there were no statistically significant differences between male and female participants in any of the tests. As there were no discrepancies found

between male and female participants in either of the participant groups, no distinction will be made between male and female for the rest of the discussion.

3.2 Temporal resolution testing

The results for the RGDT and the GIN test were as follows.

The results for the RGDT, specifically the gap detection threshold results obtained for each participant group, are depicted in Table 5.

The gap detection threshold, the shortest gap duration where the participant perceived two tones, was determined for each frequency, 500Hz to 4000 Hz, and a click stimulus. The approximate gap detection threshold was calculated (RGDTh) once the gap detection values for each frequency had been determined. Descriptive statistics of the RGDT results obtained for both groups are displayed in Table 5 with the calculated *p*-values to compare the two groups.

Table 5. The approximate (RGDTh) of the HIV- and HIV+ group

Group	**HIV- group (n=20)**				**HIV+ group (n=20)**				**P value Mann-Whitney U test**
Frequencies	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	
500 Hz	2	15	6.20	3.15	5	30	17.50	8.66	<0.001*
1000 Hz	2	15	4.40	3.23	5	30	15.00	7.43	<0.001*
2000 Hz	0	10	6.00	3.62	5	40	16.00	8.52	<0.001*
4000 Hz	0	10	4.70	3.13	5	40	17.00	8.64	<0.001*
Click	2	10	6.40	3.21	10	30	15.50	5.35	<0.001*
RGDT_Th			5.32	2.13			16.06	5.66	<0.001*

*$p \leq 0.05$ statistically significant

A significant difference in the approximate RGDTh was found between the participants in the control group and the participants in the HIV+ group for all the frequencies tested as well as for the click stimulus. The mean random gap detection threshold (RGDT_Th) calculated for the control group (5.32 ms) was within the normal limits of <8 ms, while the mean RGDT_Th (16.06 ms) of the HIV+ group fell outside the norm. The difference between the calculated p-values for the mean RGDT_Th of the performance of the HIV- and HIV+ group was statistically significant ($p<0.001$).

The GIN test consisted of two parameters namely the total percentage of correct responses and the gap detection threshold (GDTh). The differences between left and

right ears in each participant group are firstly reported and then the results of the two parameters are displayed.

- **Comparison between left and right ears**

The gap detection thresholds (GDTh) (in ms) for the left and right ears of both groups of participants are displayed in Table 6.

Table 6. GIN: GDTh's (in ms) in left and right ear

Group	Ear	Mean	SD	25th percentile	50th percentile	75th percentile	P value Wilcoxon matched pairs test
HIV+ (n=20)	Right Left	9.40 9.80	0.94 1.28	8.00 8.50	10.00 10.00	10.00 10.00	0.248
HIV- (n=20)	Right Left	5.40 5.40	0.88 0.68	5.00 5.00	6.00 5.50	6.00 6.00	1.000

*$p \leq 0.05$ statistically significant

The results in Table 6 indicate that, for the HIV+ group, the mean GDTh of the left ear was 9.80 ms and the mean GDTh for the right ear was 9.40 ms. Better GDTh's per ear were displayed in the HIV- group (mean GDTh 5.40 ms for the left ear and 5.40 ms for the right ear). Nevertheless, it is clear from Table 6 that no statistically significant difference was obtained between the left and right ears within either the HIV- (p=1.000) or the HIV+ (p=0.248) group. These results are indicative of similarities in response between ears.

The percentage (%) of correct responses for the right and left ear of both groups of participants are displayed in Table 7.

Table 7. GIN: % of correct responses for the left and right ear

Group	Ear	Mean	SD	25th percentile	50th percentile	75th percentile	P value Wilcoxon matched pairs test
HIV+ (n=20)	Right Left	45.90 43.45	5.379 5.482	43.25 40.50	46.00 44.00	49.50 46.75	0.054
HIV- (n=20)	Right Left	69.45 68.35	7.373 6.839	63.50 62.25	67.00 67.00	74.50 74.50	0.286

*$p \leq 0.05$ statistically significant

The results in Table 7 indicate that, for the HIV+ group, the mean percentage of correct response of the left ear was 43.45% and the mean percentage of correct response for the right ear was 45.90%. Better percentage of correct responses per ear was

displayed in the HIV- group (mean % of correct responses was 68.35% for the left ear and 69.45% for the right ear). Nevertheless, it is clear from Table 7 that no statistically significant difference was obtained between the left and right ear for either the HIV- (p=0.286) or the HIV+ (p=0.054) group. These results are indicative of similarities in response between ears.

- **Total percentage of correct responses**

The total percentage GIN score was calculated by adding the total number of correct responses minus the false positives divided by the total number of gaps (120 for both ears) times 100 to get the total correct percentage. The total percentages for both the control and HIV participant groups are displayed in Table 8.

Table 8. GIN: Total percentages of correct responses

Group	Mean	SD	25th percentile	50th percentile	75th percentile	P value Mann Whitney U test
HIV+ (n=20)	44.60	4.570	41.25	44.50	47.75	<0.001*
HIV- (n=20)	68.95	6.581	63.00	66.00	74.50	

*p≤0.05 statistically significant

As shown in Table 8, the mean percentages of correct responses for each gap, across all gaps detected for each test list used, indicated variability between the two participant groups. The mean percentage of correct responses for the participants in the HIV- group (without HIV) was 68.95% with SD 6.58, whereas the mean of correct responses for the participants in the HIV+ group (44.60%, ±4.57) was 24.35% lower than that of the control group. Overall, the HIV+ group displayed a poorer performance and a statistically significant difference was found between the participant groups (p<0.001).

- **Total Gap Detection Thresholds**

The total gap detection thresholds for the left and right ears (40 ears) were calculated for each participant group. These results were obtained as the GIN test is a monaural test and there was no significant difference between the ears. The results were obtained by grouping the results of each ear (in ms's) per group together and then comparing the outcomes.

Table 9. GIN: Total GD threshold left and right ears (ms)

Group	Mean	SD	25th percentile	50th percentile	75th percentile	P value Mann Whitney U test
HIV (n=20)	9.60	1.12	8.00	10.00	10.00	<0.001*
HIV- (n=20)	5.40	0.77	5.00	6.00	6.00	

**p*≤0.05 statistically significant

As shown in Table 9, the mean total GD threshold for the participants in the HIV- group (without HIV) was 5.40 ms with SD 5.00, whereas the mean of correct responses for the participants in the HIV+ group (9.60 ms ±1.12) was lower than that of the HIV- group. Overall, the HIV+ group displayed a poorer performance and a statistically significant difference was found between the participant groups (*p*= <0.001).

3.3 Speech-in-noise testing

The results for the DIN test are displayed in Table 10. Each DIN test consisted of 23 digit triplets to estimate the SNR corresponding to the 50% correct recognition probability.

Table 10. DIN results for the control and HIV group

Group	N	Min	Max	Mean	SD	P value Mann-Whitney U test
HIV+	20	-12.2	-4.4	-10.27	1.70	0.002*
HIV-	20	-12.6	-10.0	-11.5	0.69	

**p*≤0.05 statistically significant

The results in Table 10 for the DIN test indicate that the mean SNR for the participants in the HIV- group (without HIV) was -11.5 SNR with SD 0.69, whereas the mean SNR for the participants in the HIV+ group was -10.27 SNR with SD 1.70 these results indicated a statistically significant difference (*p*=0.002) between the results of the HIV- group and the HIV+ group.

Chapter 4

Discussion

4.1 Introduction

This chapter focuses on the results obtained in the study in hand and will explain the meaning, significance, and implication of the findings. This will be done with reference to existing literature in this field of study, by critically comparing research findings and attempting to draw conclusions with regards to temporal resolution and speech-in-noise abilities in adults with and without HIV.

4.2 Discussion

The aim of this research study was to determine the temporal processing skills, specifically the temporal resolution and speech-in-noise abilities, of an HIV+ adult participant group and to compare the results to results obtained from an age and gender matched HIV- participant group. The aim was achieved by gap detection tests namely the RGDT, the GIN test, and the DIN test. The discussion of the results is structured according to the presentation of the results in Chapter 4.

4.2.1 RGDT

The RGDT evaluates temporal resolution abilities, which can be defined as the capacity of the auditory system to react to rapid changes of sound over time (Owens, Campbell, Liddell, DePlacido, & Wolters, 2007). The RGDT makes use of a complex stimulus that can be useful to screen temporal resolution (Chermak & Lee, 2005). The p-values of the gap detection thresholds that were evaluated through the RGDT, labelled RGDT_Th, were significantly different for the two participant groups. In the current study a mean RGDT_Th of less than 10 ms was obtained by the HIV- group. However, a mean RGDT_Th of more than 15 ms was obtained by the HIV+ group. The poorer performance reported for the HIV+ group could possibly arise from auditory processing deficits that accompany HIV, which affect specific temporal aspects of audition such as temporal gap detection. A previous magnetic resonance imaging (MRI) study that was done on individuals with HIV found that various parts of the central auditory system including the thalamus and corpus callosum are affected by HIV (Zhan, Buckey, Fellows, & Shi, 2017). Since central auditory processing (CAP) relies on the collaboration of multiple brain areas, the central auditory deficit may correlate

with HIV-associated neurocognitive disorders (HAND) or cognitive deficits in individuals with HIV (Zhan, Buckey, Fellows, & Shi, 2017). Reports from literature concur that individuals with HIV have abnormal gap detection thresholds (Luque, et al., 2014). The control group had RGDT maximum thresholds of 10 and 15 ms at all the frequencies tested and for the click stimuli, while the maximum thresholds for the HIV group were 30 and 40 ms respectively. Yalcinkaya et al. (2009) propose that if an individual has a RGDT_Th that exceeds 20 ms he/she could possibly have temporal processing deficits. The researcher is of the opinion that the RGDT is a clinically useful tool to evaluate temporal resolution abilities in the HIV population. This processing ability is a precondition for comprehending speech in background noise as well as in quiet conditions, as speech sounds fluctuate over time (Vaidyanath & Yathiraj, 2015). In the presence of a temporal processing deficit an individual may experience difficulties with the awareness of temporal features of speech as well as breaks. These are features that typically help individuals to differentiate amongst speech sounds (Vaidyanath & Yathiraj, 2015).

4.2.2 GIN test

The GIN test will be discussed in terms of the differences between the two participant groups and an in-group comparison between the right and lefts ears relating to the percentage of correct responses and the gap detection thresholds.

In the current study the average gap detection thresholds for the HIV+ group was higher than that of the HIV- group although both groups presented with normal hearing. The participants in the HIV- group obtained a mean gap detection threshold of 5.40 ms in comparison to the HIV+ group's 9.60 ms. Normative values were obtained in a study by Samelli and Schochat (2008) and a mean gap detection threshold of approximately 4 ms was reported. Furthermore, Musiek et al. (2005) compared individuals with confirmed CNS involvement to normal-hearing listeners. The normal-hearing participant group obtained a mean gap detection threshold of 4.8 ms to 4.9 ms, whereas the participants with CNS involvement demonstrated a mean gap detection threshold of 7.8 ms to 8.5 ms (Maro et al., 2014). Therefore, it can be assumed that HIV and CNS involvement can lead to poorer temporal resolution abilities and this in turn will lead to difficulties with speech perception in noise.

The results of a previous study indicated possible CNS damage in the HIV population, as processing sound and detecting gaps in noise are known to be arduous central nervous tasks involving various areas in the brain (Zhan et al., 2018). CNS damage could be due to numerous factors, including insufficient penetration of ART into the CNS, non-adherence to drug therapy, continual HIV replication in the CNS, or continuous inflammation (Zhan et al., 2018).

The current findings are supported by research regarding auditory evoked potentials (AEP) that are used to assess neuro-electrical activity in central auditory pathways. A study by Matas et al. (2009) reported electrophysiological abnormalities in HIV+ individuals. These abnormalities mostly concerned cognitive potential and the ABR (Matas, Silva, Marcon, & Goncalves, 2009). Amongst the ABR abnormalities, the most frequently observed type was the lower brainstem impairment, characterized by increased absolute latencies of waves III and V and I-III and I-V interpeak wave latencies (Matas et al., 2009). The abnormalities were reported even before the clinical onset of symptoms such as cognitive and neurological deficits (Matas et al., 2009). It was stated that the abnormalities found during ABR testing were the result of CNS involvement. This is indicative that the brainstem structures as well as the auditory nerve are primary structures that are affected by HIV. The damage to the auditory pathway causes significant loss in the transmission of auditory information (Matas et al.,2009).

Individuals with HIV have shown abnormalities in auditory evoked potentials (AEP) in studies where auditory brainstem response (ABR) testing was done. These abnormalities were consistent with a higher rate of central processing deficits compared to individuals without HIV (Maro, Fellows, Clavier, Gui, Rieke, Wilbur et al., 2016). Pagano et al. (1992) performed an ABR study and reported prolonged ABR latencies in a group of 35 individuals with HIV, a finding which was ascribed to the effects of HIV on the CNS. A similar study was conducted by Matas et al. (2009) where ABR and Auditory Middle Latency Response (AMLR) tests were performed on 56 HIV+ individuals, some off (n=24) and on some on Antiretroviral therapy (ART) (n=32). The results showed that the HIV+ individuals who were receiving ART had a higher rate of abnormal test results. About 63% of the individuals on ART had abnormal evoked responses, but only 29% of those abnormal responses could be explained by deficits

in the peripheral hearing system. Similarly, it has been found that HIV+ individuals show a higher percentage of changed brainstem auditory evoked potential (BAEP) that indicates central auditory pathway impairment when compared to HIV- individuals (Matas, Samelli, Angrisani, Magliaro, & Segurado, 2015).

The importance of temporal resolution for speech recognition in noise has been clearly demonstrated in research (George, Festen, & Houtgast, 2006). Temporal resolution is important for understanding speech in challenging listening situations as well as in quiet conditions, because all listeners need to determine the duration of speech and silent segments and use temporal cues in order to understand what is being said (Vermeire, Knoop, Boel, Auwers, Schenus, Talaveron-Rodriquez, de Boom, & de Sloovere, 2016). Omidvar et al. (2013) concurred that there is a link between temporal resolution function and speech perception in noise. They found that adequate temporal resolution abilities are essential, since temporal resolution enables an individual to separate acoustic signals over time, an ability that is critical for speech perception in noise. It can be speculated that the temporal resolution deficits displayed by the HIV group in the current study will contribute to difficulties with speech recognition in noise.

Another parameter that was used to assess temporal resolution was the total percentage of correct responses on the GIN test. The current study showed a significant difference of 24.35% regarding the percentage of correct responses between the two participant groups. The total percentage of correct responses was determined with a fail or pass result. For a total percentage of correct response to be considered normal, results have to be ≥54%, for individuals 12 years and older (Musiek et al., 2005). According to Musiek et al. (2005) researchers making use of the GIN test should develop their own norms for the target population being studied. In the current study, the HIV+ group performed poorly as 20 (100%) participants scored ≤54%, whereas the all the participants in the HIV- group passed this aspect of the GIN test. These results indicated a significant difference between the two participant groups ($p<0.001$, Fisher's Exact test).

A previous study conducted by Musiek et al. (2005) on normal hearing individuals indicated that these participants presented with 70% gap detection responses. Similar findings were found by Samelli and Schochat (2008), as these researchers found that

participants with normal hearing presented with an average of 67.25% gap detection responses.

However, a study done on HIV infected individuals did not report on the percentage of correct responses within the HIV infected group on ART and those not receiving ART compared to a HIV negative group (Maro et al., 2014). This justifies the need for further investigation as the current study found significant differences regarding the percentage of correct responses for the two participant groups. A low percentage in this test could possibly indicate a temporal resolution deficit as the GIN is regarded as a clinically useful test to assess temporal resolution abilities and provide insight into the neural integrity of the CANS (Samelli & Schochat, 2008).

It was anticipated that the HIV+ group in the current study would perform more poorly than the HIV- group on both sections of the GIN test, including the percentage of correct responses and the gap detection threshold. This prediction was proved accurate. The researcher is of the opinion that the poorer percentage of correct gap detection responses demonstrated by the HIV+ group and the statistically significant difference in the mean GDTh ($p<0.001$) between the HIV+ and HIV- group, could be a leading cause of speech perception in noise deficits, and could possibly be attributed to HIV infection.

When the left and right ears of both participants groups were compared no significant difference was found for either group with regard to the GDTh means. The HIV- group did, however, display better GDTHs than the HIV+ group. These results correlate with results from previous studies which revealed similar gap detection thresholds for the left and right ears across their study groups (Samelli & Schochat, 2008). These results suggest that the GIN test can be administered binaurally in clinical practice (Samelli & Schochat, 2008).

The GIN test was shown to be effective in detecting temporal resolution deficits in the HIV+ group. This suggests that the GIN test could be a clinically valuable tool when used together with other auditory processing tests and speech-in-noise evaluations to further investigate possible processing difficulties. Furthermore, this test should be included in the test battery to evaluate the CANS as it can provide insight into the neural integrity of the CANS (Samelli & Schochat, 2008).

4.2.3 DIN test

Temporal resolution is said to be of importance for accurate understanding of speech in quiet conditions and in noise. In order to understand speech, a listener must be able to resolve specific temporal cues, including duration of speech segments and silent intervals as well as quick modulation of intensity (Vermeire et al., 2016).

Helfer and Vargo (2009) conducted a study on a normal hearing middle-aged woman and reported that there was no correlation between temporal resolution and speech recognition in the presence of steady-state background noise (quiet). However, when the test was presented with a competing speech situation (speech-in-noise), a correlation was found between temporal resolution and speech recognition (Helfer & Vargo, 2009). They concluded that to successfully determine whether an individual has a deficit in temporal resolution a speech masker or modulated noise should be used (Helfer & Vargo, 2009). Similarly, Torre et al. (2016) conducted a research study to evaluate the speech audiometric findings in individuals with HIV. They found that among individuals with HIV and HIV related variables (HIV viral load and CD4 cell count) there were no significant findings associated with either word recognition scores or speech recognition threshold (SRT). However, a ceiling effect was present because the tests were conducted in quiet conditions with a relatively high presentation level. Due to this, the researchers suggested that a more complex listening task, such as speech-in-noise testing, would be a more useful test to evaluate the effects of HIV on speech communication.

A common complaint in HIV+ individuals is that they have difficulty understanding speech in noise. This was also seen in a study by Maro et al. (2014). Individuals receiving treatment for HIV through ART's reported difficulties in understanding speech-in-noise. Another study was done to assess the speech-in-noise perception as a marker of cognitive impairment in HIV+ individuals. However, a weakness in the previous study was that the researchers did not make use of direct measurements to determine these specific individuals' speech-in-noise perception, but rather collected data through self-report (Zhan et al., 2018). In the current study the speech-in-noise perception was measured through the DIN test. The HIV- group had a mean of -11.5 SNR, whereas the HIV+ group obtained a mean of -10.27 SNR, a significant difference. HIV is known to damage structures of the central auditory system, which can lead to

central auditory processing (CAP) deficits. These deficits usually present as difficulty in understanding speech in noise (Zhan, Buckey, Fellows, & Shi, 2017).

Chapter 5

Conclusion and clinical implications

5.1 Conclusion

The study yielded interesting and noteworthy results. A statistically significant difference was found for the RGDT and the GIN test, both of which evaluated temporal resolution abilities and allowed comparison between the two groups of participants. This was evidenced by the gap detection thresholds that were measured in the RGDT and the GIN test. The control group had RGDT maximum thresholds of 10 and 15 ms at all the frequencies tested as well as for the click stimuli, while the maximum thresholds for the HIV+ group were 30 and 40 ms respectively. The participants in the HIV- group obtained a mean gap detection threshold of 5.40 ms in comparison to the HIV+ group's 9.60 ms. In addition, a significant difference between the two participant groups was found with the DIN test in the results of the SNR. It seems reasonable to conclude that HIV+ individuals may present with temporal resolution deficits which could contribute to speech-in-noise difficulties. The effect that HIV has on central auditory processing is, however, not fully understood yet. Therefore, additional research is needed to shed light on the extended influence that HIV has on auditory processing, cognition, attention and memory, since its prevalence continues to increase worldwide.

5.2 Clinical implications of the study

It is apparent from literature that HIV not only causes damage to the hearing organ but also affects the functioning of the CANS (Maro et al., 2014). The damage could have an impact on temporal resolution functioning and the closely related ability of speech perception in noise. Researchers have raised awareness of how important communication is to human existence and that without it, the quality of life deteriorates substantially (Dalton, Cruickshanks, Klein, Klein, Wiley, & Nondahl, 2003). The results of this study reinforce the view that audiologists should require to monitor otologic complications in individuals living with HIV, and to educate primary healthcare providers regarding potential hearing loss and auditory processing difficulties in individuals with HIV and CANS malfunctioning (Maro et al., 2014). In addition, clinicians responsible for treatment, intervention, and diagnosis in cases of HIV should

possess the necessary knowledge to refer these individuals annually for audiological evaluations since individuals could complain of speech-in-noise difficulties in the presence of normal hearing. If these individuals have otologic or speech-in-noise complaints, counselling should be provided regarding their complaints and possible intervention. The RGDT and the GIN test can be implemented in clinical practice to obtain a baseline for temporal processing, more specifically temporal resolution abilities, in individuals diagnosed with HIV. The GIN and the RGDT are suitable tests to implement clinically as both these tests offer the audiologist a reliable and quick method to assess temporal resolution while minimizing cognitive load. Furthermore, these tests are specifically useful in a South African context with multi-lingual multi-cultural individuals as both the GIN test and the RGDT minimize the linguistic demand, since individuals respond by pressing a button and it is not required of them to give a verbal answer. Moreover, the DIN test provides a feasible method to determine these individual's speech-in-noise abilities as it is an application that can be uploaded to a smartphone and can therefore be used in any clinic. A smartphone application affords an opportunity to use an English digits-in-noise test as a national test for South Africans, since English digits are used by speakers of other languages in South Africa (Potgieter et al., 2016). The DIN test can be used to determine speech-in-noise abilities in individuals with HIV. Furthermore, the RGDT and the GIN test can be used to obtain a baseline for temporal processing, specifically temporal resolution abilities in these individuals. Annual monitoring should be done with regard to audiometric testing to determine whether there is a decline in their performance on gap detection and speech-in-noise tests.

5.2 Critical evaluation of the study

The critical evaluation of the study considers of the strengths and the limitations of this study. These aspects are discussed below.

5.2.1 Strengths of the study

- The research design allowed for the HIV+ group to be age and gender matched to the HIV- group which minimized possible discountenances.
- The study included the assessment of individuals HIV+ (n=20) and HIV- (n=20) using the RGDT, the GIN test and the DIN test. The current study is one of only

a few studies to determine temporal resolution and speech-in-noise abilities in these individuals.

- This study made use of low linguistically loaded tests or materials such as the GIN test, RGDT and DIN test. These tests are specifically useful in a South African context with multi-lingual multi-cultural individuals seeing that the GIN test, RGDT and DIN test all minimize the linguistic demand, as individuals only responded by pressing a button and it was not required of them to give a verbal answer.
- A strict selection criterion was set in place to ensure that temporal resolution and speech-in-noise abilities were tested in isolation.
- A pilot study was conducted to determine the feasibility of the procedures and to increase the reliability and validity of the study.

5.2.2 Limitations of the study

- No measure of identifying the duration of HIV infection was available. This could be a confounding factor since the extent of manifestations change with time.
- This study did not determine the possible effect that the use of medication or the duration of use of medication could have on the results.
- The small sample size (n=40) could be a limitation of this study with regards to the generalization of the results. Larger sample sizes should be tested and compared in future studies.

5.3 Recommendations for future research

The results of this study revealed opportunities for further research regarding the following:

- Future research should examine the association between the duration of HIV and performance on the GIN test to determine if patients who are HIV+ for a longer duration are more likely to develop difficulties in temporal processing and speech perception in noise.
- The DIN test made use of digits that were presented in the presence of noise. A more complex speech-in-noise test could be done, using specific words instead of digits.

- It is recommended that future research be conducted to determine the effect of different medications used to treat HIV, on the CNS and auditory processing mechanism.
- Quality of life studies for HIV+ individuals using standardised questionnaires should be considered, to determine the functional implications or difficulties with central auditory processing.
- Future research should be done on the HIV population to determine a correlation between central auditory processing deficits and cognitive difficulties related to HIV as it progresses.

5.4 Final comment

South Africa is characterised by a high burden of disease. This study provided more information on the effects of HIV on speech perception in noise, auditory information processing and more explicitly on temporal resolution. If performance on central auditory tests can be shown to be an early marker of central nervous damage in HIV infection, detecting these early changes in clinical practice could lead to changes in treatment (Zhan et al., 2018). Extensive research in this field should be done so that the auditory complications this population may experience will become known. The contribution of evidence-based practices and findings to the developing body of literature in the areas of HIV and audiology will benefit patients and practitioners alike.

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Appendices

Appendix A

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/30/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 01/14/2020.

26 April 2019

Approval Certificate
New Application

Ethics Reference No.: HUM019/0119
Title: Temporal Resolution and Speech Perception-in-Noise of adults with and without HIV/AIDS

Dear Miss MJ Wartenaar

The **New Application** as supported by documents received between 2019-01-25 and 2019-04-24 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-04-24.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-04-26.
- Please remember to use your protocol number (HUM019/0119) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

Research Ethics Committee
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Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

Appendix B

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

STEVE BIKO ACADEMIC HOSPITAL

Enquiries: Dr JS Mangwane
Tel No: +2712 345 2018
Fax No: +2712 354 2151
e-mail: joseph.mangwane@gauteng.gov.za

For attention: ___ Ms Michaela Wantenaar

NHRD Ref Number: GP_201905_012

SBAH Ref Number: _____**SBAH 201905 23**

Re: REQUEST FOR PERMISION TO CONDUCT RESEARCH AT STEVE BIKO ACADEMIC HOSPITAL

TITLE:

Temporal resolution and speech perception in noise of adults with and without HIV.

Permission is hereby granted for the above-mentioned research to be conducted at Steve Biko Academic Hospital.
This is done in in accordance to the "Promotion of access to information act No 2 of 2000".
Please note that in addition to receiving approval from Hospital Research Committee, the researcher is expected to seek permission from all relevant department.
Furthermore, collection of data and consent for participation remain the responsibility of the researcher.
The hospital will not incur extra cost as a result of the research being conducted within the hospital.
You are also required to submit your final report or summary of your findings and recommendations to the office of the CEO.

Approved

Comment: _____

_____

_____

Date: 2019 -05- 20

Dr. J S. Mangwane
Manager: Medical Service

Appendix C

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

LETTER TO REQUEST PERMISSION FROM THE HOSPITAL

Steve Biko Academic Hospital

January 2019

The Infectious Disease Clinic
Steve Biko Academic Hospital
Pretoria

Dear Professor Anton Stoltz,

RE: PERMISSION TO CONDUCT A RESEARCH STUDY

I, Michaela Wantenaar (Student number: 15193382; ID number 9611080079085) am a postgraduate master's student from the Department of Speech-Language Pathology and Audiology, University of Pretoria, in 2019. As per the requirements of the MA (Audiology) degree, I am required to conduct a research project, under the supervision of Prof. L Pottas (Audiologist) and Prof. M Soer (Audiologist). I hereby request permission to approach patients from the Infectious Disease Clinic at Steve Biko Academic Hospital. If permission is granted, I plan to start with data collection from April 2019. The following information form the research is shared with you.

The title of my study is: **The temporal resolution and speech perception in noise of adults with and without HIV with normal audiometric results.**

The aim of this study is to determine and compare temporal resolution and speech-in-noise perception in adults with and without HIV with normal audiometric results, using the Gaps-In-Noise (GIN) test, the Digits-In-Noise (DIN) test and the Random Gap Detection Test (RGDT).

Participants in the HIV group will undergo a single assessment, with an approximate duration of two hours per assessment, that will take place in the Audiology Department of Steve Biko Academic Hospital. I intend to do the study through means of an interview with the identified adults. Participants will undergo an audiological diagnostic test battery (acoustic immittance measurements and pure tone audiometry) and auditory

processing tests (Digits-In-Noise test (DIN), Gaps-In-Noise (GIN) test and Random Gap Detection Test (RGDT)).

I sincerely believe that this research will be of benefit to the field of audiology and HIV management and will allow for evidence-based practice which will improve the quality of the services provided.

In order to conduct this study, clinical and outcome data of HIV positive adult patients of the ID clinic will be captured. If permission for this is granted from you as the coordinator of the Infectious Disease Clinic, you are requested to sign this letter of consent.

Please contact me should you require more information. Thank you in advance for your time and cooperation.

Kind regards,

Ms Michaela Wantenaar
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Tel: 0823951530
E-mail: *michaela.wantenaar@gmail.com*

Prof Lidia Pottas
Supervisor
E-mail: *lidia.pottas@up.ac.za*

Prof Maggi Soer
Supervisor
E-mail: *maggi.soer@up.ac.za*

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

PERMISSION FOR THE USE OF INFORMATION OF HIV POSITIVE ADULTS FROM THE INFECTIOUS DISEASE CLINIC (ID) IN STEVE BIKO ACADEMIC HOSPITAL (SBAH)

Herewith I, **Professor Anton Stoltz** give written permission that the researcher may approach patients of the ID clinic and use the information of HIV positive adults from the ID clinic for the research project titled: *The temporal resolution and speech perception in noise of adults with and without HIV with normal audiometric results.*

Professor Anton Stoltz

Coordinator: Infectious Disease Clinic

Date: 17/1/2019

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Departement Spraak-Taalpatologie en Oudiologie
Lefapha la Bomotho
Kgoro ya Phatholotši ya Polelo-Maleme le Go kwa

Appendix D

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

LETTER TO REQUEST PERMISSION FROM THE AUDIOLOGY DEPARTMENT

Steve Biko Academic Hospital

January 2019

The Audiology Department
Steve Biko Academic Hospital
Pretoria

Dear Ms Bontle Baloyi,

RE: PERMISSION TO CONDUCT A RESEARCH STUDY

I, Michaela Wantenaar (Student number: 15193382; ID number 9611080079085) am a postgraduate master's student from the Department of Speech-Language Pathology and Audiology, University of Pretoria, in 2019. As per the requirements of the MA (Audiology) degree, I am required to conduct a research project, under the supervision of Prof. L Pottas (Audiologist) and Prof. M Soer (Audiologist). I hereby request permission to test patients at the Audiology Department from the Infectious Disease Clinic at Steve Biko Academic Hospital. If permission is granted, I plan to start with data collection from April 2019. The following information form the research is shared with you.

The title of my study is: **The temporal resolution and speech perception in noise of adults with and without HIV with normal audiometric results.**

The aim of this study is to determine and compare temporal resolution and speech-in-noise perception in adults with and without HIV with normal audiometric results, using the Gaps-In-Noise (GIN) test, the Digits-In-Noise (DIN) test and the Random Gap Detection Test (RGDT).

Participants in the HIV group will undergo a single assessment, with an approximate duration of two hours per assessment. I intend to do the study through means of an interview with the identified adults. Thirty participants will undergo an audiological diagnostic test battery (acoustic immittance measurements and pure tone audiometry) and auditory processing tests (Digits-In-Noise test (DIN), Gaps-In-Noise (GIN) test and

Random Gap Detection Test (RGDT)). The testing will take place in the afternoons for a duration of eight weeks at this respective Department.

I sincerely believe that this research will be of benefit to the field of audiology and HIV management and will allow for evidence-based practice which will improve the quality of the services provided.

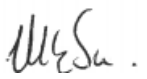
In order to conduct this study, clinical and outcome data of HIV positive adult patients of the ID clinic will be captured. If permission for this is granted from you, you are requested to sign this letter of consent.

Please contact me should you require more information. Thank you in advance for your time and cooperation.

Kind regards,

Ms Michaela Wantenaar
Student Researcher
Tel: 0823951530
E-mail: *michaela.wantenaar@gmail.com*

Prof Lidia Pottas
Supervisor
E-mail: *lidia.pottas@up.ac.za*



Prof Maggi Soer
Supervisor
E-mail: *maggi.soer@up.ac.za*

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

PERMISSION TO TEST HIV POSITIVE ADULTS FROM THE INFECTIOUS DISEASE CLINIC (ID) IN STEVE BIKO ACADEMIC HOSPITAL (SBAH) AT THE AUDIOLOGY DEPARTMENT

Herewith I, **Ms Bontle Baloyi** give written permission that the researcher may test HIV positive adults at the Audiology Department from the ID clinic for the research project titled: *The temporal resolution and speech perception in noise of adults with and without HIV with normal audiometric results.*

Ms Bontle Baloyi

Audiology Department

Date: 01/22/2019

University of Pretoria, Private Bag X20
Hatfield 0028, South Africa
Tel +27 (0)12 420 2357
Fax +27 (0)12 420 3517
www.up.ac.za

Fakulteit Geesteswetenskappe
Departement Spraak-Taalpatologie en Oudiologie
Lefapha la Bomotho
Kgoro ya Phatholotši ya Polelo-Maleme le Go kwa

Appendix E

Special Communication

World Medical Association Declaration of Helsinki
Ethical Principles for Medical Research Involving Human Subjects

World Medical Association

Adopted by the 18th WMA General Assembly, Helsinki, Finland, June 1964, and amended by the:
29th WMA General Assembly, Tokyo, Japan, October 1975
35th WMA General Assembly, Venice, Italy, October 1983
41st WMA General Assembly, Hong Kong, September 1989
48th WMA General Assembly, Somerset West, Republic of South Africa, October 1996
52nd WMA General Assembly, Edinburgh, Scotland, October 2000
53rd WMA General Assembly, Washington, DC, USA, October 2002 (Note of Clarification added)
55th WMA General Assembly, Tokyo, Japan, October 2004 (Note of Clarification added)
59th WMA General Assembly, Seoul, Republic of Korea, October 2008
64th WMA General Assembly, Fortaleza, Brazil, October 2013

Preamble

1. The World Medical Association (WMA) has developed the Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data.

   The Declaration is intended to be read as a whole and each of its constituent paragraphs should be applied with consideration of all other relevant paragraphs.

2. Consistent with the mandate of the WMA, the Declaration is addressed primarily to physicians. The WMA encourages others who are involved in medical research involving human subjects to adopt these principles.

General Principles

3. The Declaration of Geneva of the WMA binds the physician with the words, "The health of my patient will be my first consideration," and the International Code of Medical Ethics declares that, "A physician shall act in the patient's best interest when providing medical care."

4. It is the duty of the physician to promote and safeguard the health, well-being and rights of patients, including those who are involved in medical research. The physician's knowledge and conscience are dedicated to the fulfillment of this duty.

5. Medical progress is based on research that ultimately must include studies involving human subjects.

6. The primary purpose of medical research involving human subjects is to understand the causes, development and effects of diseases and improve preventive, diagnostic and therapeutic interventions (methods, procedures and treatments). Even the best proven interventions must be evaluated continually through research for their safety, effectiveness, efficiency, accessibility and quality.

7. Medical research is subject to ethical standards that promote and ensure respect for all human subjects and protect their health and rights.

8. While the primary purpose of medical research is to generate new knowledge, this goal can never take precedence over the rights and interests of individual research subjects.

9. It is the duty of physicians who are involved in medical research to protect the life, health, dignity, integrity, right to self-determination, privacy, and confidentiality of personal information of research subjects. The responsibility for the protection of research subjects must always rest with the physician or other health care professionals and never with the research subjects, even though they have given consent.

10. Physicians must consider the ethical, legal and regulatory norms and standards for research involving human subjects in their own countries as well as applicable international norms and standards. No national or international ethical, legal or regulatory requirement should reduce or eliminate any of the protections for research subjects set forth in this Declaration.

11. Medical research should be conducted in a manner that minimises possible harm to the environment.

12. Medical research involving human subjects must be conducted only by individuals with the appropriate ethics and scientific education, training and qualifications. Research on patients or healthy volunteers requires the supervision of a competent and appropriately qualified physician or other health care professional.

Appendix F

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

Study Title: Temporal resolution and speech perception in noise in adults with and without HIV with normal audiometric results.

Supervisors: Prof. L Pottas and Prof. M Soer

Principal Investigator: Michaela Wantenaar

Institution: University of Pretoria

Daytime telephone number: 082 395 1530

DATE AND TIME OF INFORMED CONSENT DISCUSSION:

dd	mmm	year

:
Time

Dear Prospective Participant

1) INTRODUCTION

You are invited to volunteer for a research study. I am doing this research for a Master's degree at the University of Pretoria. The information in this document is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions, which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

2) THE NATURE AND PURPOSE OF THIS STUDY

You are invited to take part in a research study. The aim of this study is to determine the temporal resolution and speech perception in noise in adults with and without HIV. An interview will be conducted to assess general health. Diagnostic auditory assessments will be used to establish auditory thresholds (hearing ability). Thereafter

auditory processing assessments will be conducted to assess speech-in-noise abilities. By doing so we wish to learn more about how auditory processing abilities can possibly be affected.

3) PARTICIPANT CANDIDACY

For this study, participants are required to be HIV positive adults between the ages of 18-40 years. If you consent, I will need to collect all necessary information from your hospital file, for e.g. your HIV status, ARV usage and CD4 cell counts.

4) EXPLANATION OF PROCEDURES TO BE FOLLOWED

In this study participants will be required to complete the following tests and actions:

	Test Name	Requirements
PROCEDURES	Interview	Answer questions during an interview to obtain background information.
	Acoustic Immittance	You will need to sit still, whilst a soft probe will be placed into your ear. You will feel a slight pressure build up in your ear, please do not talk or swallow whilst the probe is in your ear.
	Pure Tone Audiometry	There will be a series of "beeps" played to you, please press the button every single time you hear the "beep".
	Digits-In-Noise test	In the presence of background noise, you will hear three numbers that you have to type in on a cell phone.
	Gaps-In-Noise test	You need to press the button every time a gap is noise is perceived.
	Random Gap Detection Test	It will be expected of you to count the number of tones or clicks heard presented at the same time in both ears. You will either have to respond verbally or non-verbally by raising one or two fingers.

5) TEST DURATION AND VENUE

You will only need to come for testing once and testing will approximately take 90 minutes. All testing will be conducted at the Audiology Department in Steve Biko Academic Hospital, where patients will be invited to participate when visiting the Infectious Disease Clinic.

6) RISK AND DISCOMFORT INVOLVED

There is no foreseeable physical discomfort or risk involved. If there are questions that are too sensitive for you to answer, you do not need to answer them.

7) POSSIBLE BENEFITS OF THIS STUDY

You as a participant in this study will receive hearing tests at no cost to you. The results of the hearing tests will be disclosed to you and should we find that your hearing is impaired, the researcher will refer you to an appropriate clinic/facility for treatment. The data collected from this study will aid in advancing auditory processing abilities data in HIV positive individuals.

8) I understand that if I do not want to participate in this study, I may decline.

9) I may at any time withdraw from this study, without any negative consequences.

10) HAS THE STUDY RECEIVED ETHICS APPROVAL?

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4-59, Telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the Declaration may be obtained from the investigator should you wish to review it.

11) INFORMATION

Should you have any questions or concerns regarding any aspect of this study, please feel free to contact Ms. Wantenaar at: Tel: +27 82 395 1530 or via E-mail at: michaela.wantenaar@gmail.com. Alternatively, you may contact my supervisors: Prof Lidia Pottas at: lidia.pottas@up.ac.za; Prof Maggi Soer at: maggi.soer@up.ac.za.

12) CONFIDENTIALITY

Personal information and results from participants are to be kept strictly confidential during the data analysis and reporting processes of this study. In order to ensure the confidentiality during the statistical analysis of the participant's data in this study, alpha-numeric codes will be allocated to each participant. The participant's data will be saved and reported using the alpha-numeric codes. These codes are only to be

known to the researcher and the supervisors of this study. Consequently, the participants are not identifiable when the researcher report is written up in article - and dissertation format.

13) CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
I have also received, read and understood the above written information about the study.
I have had adequate time to ask questions and I have no objections to participate in this study.
I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
I understand that I will not be penalised in any way should I wish to discontinue with the study and my withdrawal will not affect my employment or student status.
I am participating willingly.
I have received a signed copy of this informed consent agreement.

Participant's Name: _____
(Please print)

Participant's Signature: _____ **Date:** _____

Researcher's Name: _____
(Please print)

Researcher's Signature: _____ **Date:** _____

Witness's Name: _____
(Please print)

Witness's Signature: _____ **Date:** _____

AFFIRMATION OF INFORMED CONSENT BY AN ILLITERATE PARTICIPANT

(if suitable)

I, the undersigned, _____ have read and have explained fully to the participant, named _____, the participant informed consent document, which describes the nature and purpose of the study in which I have asked the participant to participate. The explanation I have given has mentioned both the possible risks and benefits of the study. The participant indicated that he/she understands that he/she will be free to withdraw from the study at any time for any reason and without jeopardizing his/her standard care.

I hereby certify that the participant has agreed to participate in this study.

Participant's Name: _____

(Please print)

Participant's Signature: _____ **Date:** _____

Researcher's Name: _____

(Please print)

Researcher's Signature: _____ **Date:** _____

Witness's Name: _____

(Please print)

Witness's Signature: _____ **Date:** _____

Appendix G

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

Study Title: Temporal resolution and speech perception in noise in adults with and without HIV with normal audiometric results.

Supervisors: Prof. L Pottas and Prof. M Soer

Principal Investigator: Michaela Wantenaar

Institution: University of Pretoria

Daytime telephone number: 082 395 1530

DATE AND TIME OF INFORMED CONSENT DISCUSSION:

dd	mmm	year

:
Time

Dear Prospective Participant

1) INTRODUCTION

You are invited to volunteer for a research study. I am doing this research for a Master's degree at the University of Pretoria. The information in this document is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions, which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

2) THE NATURE AND PURPOSE OF THIS STUDY

You are invited to take part in a research study. The aim of this study is to determine the temporal resolution and speech perception in noise in adults with and without HIV. An interview will be conducted to assess general health. Diagnostic auditory assessments will be used to establish auditory thresholds (hearing ability). Thereafter

auditory processing assessments will be conducted to assess speech-in-noise abilities. By doing so we wish to learn more about how auditory processing abilities can possibly be affected.

3) PARTICIPANT CANDIDACY

For this study, HIV negative adults are required to be between the ages of 18-40 years and in overall good general health as well as have normal hearing. If you consent, as a voluntary participant with an HIV⁻ status, you are required to have underwent/ be willing to undergo an HIV screening. These participants will only be recruited who have attended voluntary HIV screening at a healthcare clinic on their own accord. Participants may have the screening done at the DisChem Clinic in Hillcrest, Pretoria should they wish to do so. HIV screening costs will be covered by the researcher. Proof of the aforementioned screening will then be needed to be presented to the researcher before testing can commence. In the event where the screen indicates a positive result, the staff at the clinic that administered the test will provide counselling to you. Thereafter, if you do still wish to participate in this study, you will be assigned to the HIV group.

If, however you decline to know your HIV status, you will be excluded from the study without any negative consequences.

4) EXPLANATION OF PROCEDURES TO BE FOLLOWED

In this study participants will be required to complete the following tests and actions:

	Test Name	Requirements
PROCEDURES	Interview	Answer questions during an interview to obtain background information.
	Acoustic Immittance	You will need to sit still, whilst a soft probe will be placed into your ear. You will feel a slight pressure build up in your ear, please do not talk or swallow whilst the probe is in your ear.
	Pure Tone Audiometry	There will be a series of “beeps” played to you, please press the button every single time you hear the “beep”.
	Digits-In-Noise test	In the presence of background noise, you will hear three numbers that you have to type in on a cell phone.
	Gaps-In-Noise test	You need to press the button every time a gap is noise is perceived.
	Random Gap Detection Test	It will be expected of you to count the number of tones or clicks heard presented at the same time in both ears. You will either have to respond verbally or non-verbally by raising one or two fingers.

5) TEST DURATION AND VENUE

You will only need to come for testing once and testing will approximately take 90 minutes. All testing will be conducted at the Speech-Language Pathology and Audiology Department at the University of Pretoria.

6) RISK AND DISCOMFORT INVOLVED

There is no foreseeable physical discomfort involved. A possible risk for this study is that you could obtain information pertaining to your HIV status, that you were not aware of i.e. a HIV positive result. If there are questions that are too sensitive for you to answer, you do not need to answer them.

7) POSSIBLE BENEFITS OF THIS STUDY

You as a participant in this study will receive hearing tests at no cost to you. The results of the hearing tests will be disclosed to you and should we find that your hearing is impaired, the researcher will refer you to an appropriate clinic/facility for treatment. The data collected from this study will aid in advancing auditory processing abilities data in HIV positive individuals. Participants will be reimbursed for costs incurred in the study, such as transport to the site as well as the costs of the screening test.

8) I understand that if I do not want to participate in this study, I may decline.

9) I may at any time withdraw from this study, without any negative consequences.

10) HAS THE STUDY RECEIVED ETHICS APPROVAL?

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4-59, Telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research

involving humans. A copy of the Declaration may be obtained from the investigator should you wish to review it.

11) INFORMATION

Should you have any questions or concerns regarding any aspect of this study, please feel free to contact Ms. Wantenaar at: Tel: +27 82 395 1530 or via E-mail at: michaela.wantenaar@gmail.com. Alternatively, you may contact my supervisors: Prof Lidia Pottas at: lidia.pottas@up.ac.za; Prof Maggi Soer at: maggi.soer@up.ac.za.

12) CONFIDENTIALITY

Personal information and results from participants are to be kept strictly confidential during the data analysis and reporting processes of this study. In order to ensure the confidentiality during the statistical analysis of the participant's data in this study, alpha-numeric codes will be allocated to each participant. The participant's data will be saved and reported using the alpha-numeric codes. These codes are only to be known to the researcher and the supervisors of this study. Consequently, the participants are not identifiable when the researcher report is written up in article - and dissertation format.

13) CONSENT TO PARTICIPATE IN THIS STUDY

I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
I have also received, read and understood the above written information about the study.
I have had adequate time to ask questions and I have no objections to participate in this study.
I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
I understand that I will not be penalised in any way should I wish to discontinue with the study and my withdrawal will not affect my employment or student status.
I am participating willingly.

I have received a signed copy of this informed consent agreement.

Participant's Name: _____

(Please print)

Participant's Signature: _____ **Date:** _____

Researcher's Name: _____

(Please print)

Researcher's Signature: _____ **Date:** _____

Witness's Name: _____

(Please print)

Witness's Signature: _____ **Date:** _____

AFFIRMATION OF INFORMED CONSENT BY AN ILLITERATE PARTICIPANT

(if suitable)

I, the undersigned, _____ have read and have explained fully to the participant, named _____, the participant informed consent document, which describes the nature and purpose of the study in which I have asked the participant to participate. The explanation I have given has mentioned both the possible risks and benefits of the study. The participant indicated that he/she understands that he/she will be free to withdraw from the study at any time for any reason and without jeopardizing his/her standard care.

I hereby certify that the participant has agreed to participate in this study.

Participant's Name: _____

(Please print)

Participant's Signature: _____ **Date:** _____

Researcher's Name: _____

(Please print)

Researcher's Signature: _____ **Date:** _____

Witness's Name: _____

(Please print)

Witness's Signature: _____ **Date:** _____

Appendix H

ICD 6

PARTICIPANT INFORMED CONSENT FOR HUMAN IMMUNODEFICIENCY VIRUS (HIV) TESTING

Study title: Temporal resolution and speech perception in noise of adults with and without HIV.

Principal Investigator: Michaela Wantenaar

Supervisor: Prof Lidia Pottas, Prof Maggi Soer

Institution: University of Pretoria

DAYTIME AND AFTER HOURS TELEPHONE NUMBER(S):

Daytime number/s: ……

Afterhours number: ……

Date and time of first informed consent discussion:

			:
date	**month**	**year**	**Time**

Dear Prospective Participant

Dear Mr. / Mrs. ……

1) INTRODUCTION

You are being invited to undergo a human immunodeficiency virus (HIV) test to test if you are positive for HIV. Before agreeing to participate in this research study, it is important that you read and understand the following information on HIV testing.

2) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS

You will receive counseling both before and after you have taken the test. The HIV test will be carried out on a sample of your blood. The test can detect antibodies made by your immune system when HIV is present. The HIV antibody test is used to determine if you have been infected with HIV. A HIV test is extremely accurate if performed three months after exposure to HIV.

A negative test means that it is unlikely that you are infected with HIV. If you had a recent exposure (less than three months ago), a HIV test will need to be repeated to confirm that you are not in the “window” period of HIV infection, before the antibodies are present.

A confirmed HIV-positive test means that it is very likely that you have been infected with HIV. This test does not determine how advanced the illness is and is it not a test for AIDS. Medical care and additional testing will be needed to help plan treatment.

You will be referred to a specialist clinic for further testing and counseling. The clinic is required to provide counseling and treatment that conforms to the national standard of care for HIV prevention and treatment.

3) ADVANTAGES AND DISADVANTAGES OF HUMAN IMMUNODEFICIENCY VIRUS TESTING:

Advantages of HIV testing include:

- Making yourself available to health care and counselling for HIV which has many benefits.
- Preventing the spread of HIV to your sexual partners.
- Informing your partner so that he or she can also prevent the spread of HIV.
- Avoiding blood donations.
- Preventing the spread of HIV from mother-to-child.

Disadvantages of HIV testing may include:

- Feeling emotional stress, depression and despair.

- Feeling shamed.
- Feeling judged.
- Feeling rejected by family, friends, sexual partners and/or spouse.

The advantages and disadvantages should be carefully considered before signing the consent form.

4) POTENSIAL RISKS AND DISCOMFORTS

Possible side-effects from drawing blood include feeling faint, inflammation of the vein, pain, bruising or bleeding at the site of puncture.

5) COMPENSATION

You will not be paid to take part in the study. Participants will be reimbursed for costs incurred in the study, such as transport to the site as well as the costs of the screening test.

6) YOUR RIGHTS AS A RESEARCH PARTICIPANT

Your participation in this study is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. Your withdrawal will not affect your access to other medical care.

7) ETHICS APPROVAL

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

8) CONFIDENTIALITY

Your HIV testing information and test results cannot be released to anyone without your written consent. General consent to health care and information release does not cover HIV-related information. If you are found to be HIV infected, you are personally not required to tell anyone about this diagnosis. However, it is very important to notify your sexual partners and those who might have been exposed to your blood.

9) INFORMED CONSENT STATEMENT

1. I confirm that I have read and understood the above information document, and that I have been informed about the nature, conduct, and potential benefits and risks of HIV testing, and have had the opportunity to ask questions.	
2. I understand that I will be informed of the results of the test in confidence, and that should the result be positive, I will be advised about further counselling and care.	
3. I will receive a signed copy of the *Patient information Document and Consent Document for HIV testing.*	

_____

Printed name of participant

_____ _____

Participant signature Date

MICHAELA JULIANA WANTENAAR

Printed name of Investigator

_____ _____

Signature of Investigator Date

Appendix I

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

Principal Investigator(s) Declaration for the storage of research data and/or documents

I, the Principal Investigator, Michaela Wantenaar of the following study titled

TEMPORAL RESOLUTION AND SPEECH PERCEPTION IN NOISE OF ADULTS WITH AND WITHOUT HUMAN IMMUNODEFICIENCY VIRUS will be storing all the research data and/or documents referring to the above mentioned study at the following address:

Department of Speech-Language Pathology and Audiology

University of Pretoria

Corner of Lynwood Road and Roper Street

Hatfield

Pretoria

South Africa

START DATE OF TRIAL/STUDY: January 2019

END DATE OF TRIAL/STUDY: December 2019

I understand that the storage of the abovementioned data and/or documents must be maintained for a minimum of 15 years from the commencement of this study.

START OF STORAGE DATE: January 2020 until

END OF STORAGE DATE: January 2035

Name: Michaela Juliana Wantenaar

Signature: 

Date: 2019/01/21

Appendix J

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

DECLARATION

I, Michaela Juliana Wantenaar (Student no.: 15193382; ID no.: 9611080079085), declare that the development of this research proposal is my own work and has not previously been submitted. I acknowledge and understand that plagiarism is wrong.

Where secondary material has been used, it has been acknowledged and referenced in accordance with the University of Pretoria's requirements. I am aware of university policies and implications regarding plagiarism.

2019/01/21

Michaela Juliana Wantenaar

Date

University of Pretoria, Private Bag X20
Hatfield 0028, South Africa
Tel +27 (0)12 4202816
www.up.ac.za

Fakulteit Geesteswetenskappe
Departement Spraak-Taalpatologie en Oudiologie
Lefapha la Bomotho
Kgoro ya Phatholotši ya Polelo-Maleme le Go kwa

Appendix K

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

PARTICIPANT FEEDBACK LETTER

TEMPORAL RESOLUTION AND SPEECH PERCEPTION IN NOISE OF ADULTS WITH HIV

Participant: _____

Date of assessment: _____

Hospital: _____

Dear Participant,

Thank you for participating in the above-mentioned research study.

The following tests were performed:

Auditory evaluation

Tympanometry

Acoustic Reflex Measurements

Pure tone audiometry

Auditory Processing evaluation

Gaps-In-Noise test (GIN)

Random Gap Detection Test (RGDT)

Digit-In-Noise test (DIN)

Considering the test results obtained, it is recommended that you visit an:

- ☐ Audiologist for a diagnostic hearing evaluation
- ☐ Ear Nose and Throat Specialist/General Practitioner
- ☐ Other

Reasons for referral

_____

_____

_____

Kind Regards,

_____

Michaela Wantenaar

(Student Researcher)

Appendix L

INTERVIEW QUESTION LIST

1. Does anyone in your family have childhood hearing loss?

2.1 Have you ever had your hearing tested before?

2.2 If yes, what were the results?

3.1 Do you experience any problems with your hearing?

3.2 Did these problems start suddenly, or did it progress slowly?

3.3 How often does your hearing problem cause you to struggle hearing people?

3.4 Do you struggle to follow speech when it is noisy?

4. Do you ever experience any ear pain?

5.1 Have you been exposed to loud noise before?

5.2 If yes, state the environment? Eg working in a factory

5.3 For how long have you been exposed to this loud noise?

6.1 Do you experience a ringing or whistling sound in your ear/s?

6.2 If yes, how often do you experience this sound?

6.3 Is it in one or both ear/s?

6.4 To what extent does this ringing sound affect you?

6.5 When did you hear it for the first time?

7.1 Do you ever experience dizziness or imbalance?

7.2 If yes, how often do you experience this?

8.1 Have you had any surgeries in your ear, nose or throat?

8.2 If yes, what and when?

9.1 Have you experienced any physical trauma to the ear or head?

9.2 If yes, what and when?

10.1 Are you currently on any medication?

10.2 If yes, what medication?

11. Do you partake in underwater diving?

Appendix M

DATA CAPTURE SHEET FOR PARTICIPANTS WITH AND WITHOUT HIV

Date of assessment: _____

Hospital: _____

Randomized participant number: _____

Contact number: _____

HIV status: Positive □ Negative □

If positive, duration of HIV and CD4 count: _____

Age: _____

Gender: _____

Medication: _____

Tympanometry:

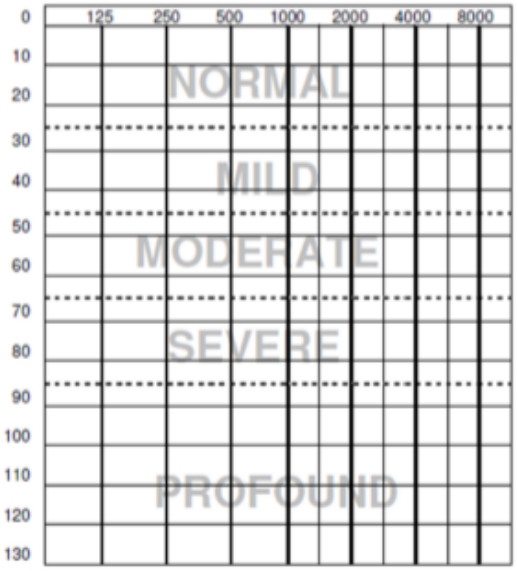
	Right ear	Left ear
Tympanogram type		
Static compliance		
Ear canal pressure		
Ear canal volume		

Acoustic reflex measurements:

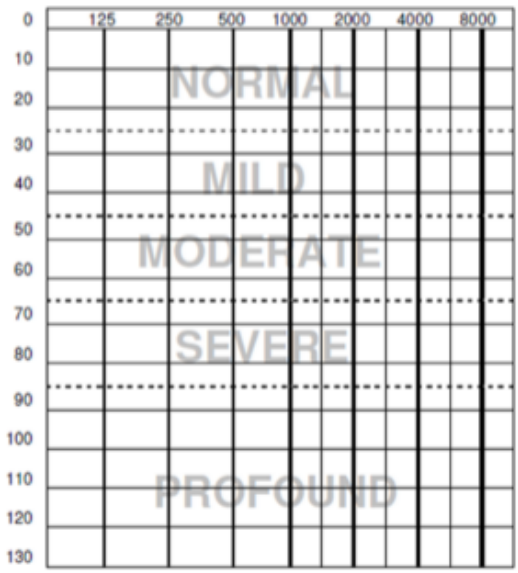
	Right ear	Left ear
500Hz		
1000Hz		
2000Hz		
4000Hz		

Pure tone audiometry:

Regteroor / Right Ear



Linkeroor / Left Ear



PTA: _____

PTA: _____

Digits-In-Noise (DIN) test

SNR: _____

Gaps-In-Noise (GIN) test

Duration Threshold	2 ms	3 ms	4 ms	5 ms	6 ms	8 ms	10 ms	12 ms	15 ms	20 ms	Total
List 1	6	6	6	6	6	6	6	6	6	6	60
	%	%	%	%	%	%	%	%	%	%	%

Duration Threshold	2 ms	3 ms	4 ms	5 ms	6 ms	8 ms	10 ms	12 ms	15 ms	20 ms	Total
List 2	6	6	6	6	6	6	6	6	6	6	60
	%	%	%	%	%	%	%	%	%	%	%

Duration Threshold	2 ms	3 ms	4 ms	5 ms	6 ms	8 ms	10 ms	12 ms	15 ms	20 ms	Total
List 3	6	6	6	6	6	6	6	6	6	6	60
	%	%	%	%	%	%	%	%	%	%	%

Duration Threshold	2 ms	3 ms	4 ms	5 ms	6 ms	8 ms	10 ms	12 ms	15 ms	20 ms	Total
List 4	6	6	6	6	6	6	6	6	6	6	60
	%	%	%	%	%	%	%	%	%	%	%

Random Gap Detection Test (RGDT)

Tones

Subset 1 (practice subset): Smallest / lowest gap in ms -

Subset 2 (tonal/click subset):

- 500 Hz – GDTh:
- 1000 Hz – GDTh:
- 2000 Hz – GDTh:
- 4000 Hz – GDTh:

Clicks

Subset 3 (practice subset): Smallest / lowest gap in ms –

Subset 4 (tonal/click subset): Smallest / lowest gap in ms **–**

Totals

Duration Threshold	2 ms	3 ms	4 ms	5 ms	6 ms	8 ms	10 ms	12 ms	15 ms	20 ms	Total
Total	/12	/12	/12	/12	/12	/12	/12	/12	/12	/12	/120
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**

False positives Right ear: _____

False positives Left ear: _____

Gap detection threshold Right ear: _____

Gap detection threshold Left ear: _____

Total score in % = Total correct – False Positives / Total of Trials X 100

Appendix N

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

Date: 22 January 2019

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student(s), with the Name(s): ***Michaela Wantenaar***

Studying at the ***University of Pretoria***

discussed the Project with the title: **"*Temporal Resolution and Speech Perception in Noise of adults with and without HIV*"** with me.

I hereby confirm that I am aware of the project and also undertake to assist with the Statistical analysis of the data generated from the project.

The analytical tool that will be used will be**: a power analysis by making use of SPSS**

to achieve the objective(s) of the study.

Name: **Dr MA Graham** Date: **22 January 2019**

Signature:  Tel: **012 420 6637**

Department or Unit: **Previously employed at the Department of Statistics, University of Pretoria, 2004 – 2013; holds a PhD in Mathematical Statistics. Currently employed at the Faculty of Education, University of Pretoria.**

The certified copy of my PhD represent my stamp.

04196841

Certified a true copy of the original document. There is no indication that the original document has been amended by unauthorised persons.
Gewaarmerk 'n waar afskrif van die oorspronklike dokument daar is geen aanduiding dat die oorspronklike dokument deur ongemagtigde persone gewysig is nie.

Walter Stephen Graham
Client Services Manager
Alexander Forbes Financial Services
Commissioner of Oaths (Ex Officio)

University of Pretoria

The Council and Senate hereby declare that
at a congregation of the University the degree

Doctor of Philosophy
in
Mathematical Statistics

with all the associated rights and privileges
was conferred on

Marien Alet Graham

in terms of the Higher Education Act, 1997 and the Statute of the University

On behalf of the Council and Senate

Vice-Chancellor and Principal

On behalf of the Faculty of
Natural and Agricultural Sciences

Dean

Registrar

2013-09-06

Appendix O

DECLARATION BY PRINCIPAL INVESTIGATOR AND SUB-INVESTIGATOR

Name: Michaela Wantenaar

Trial: N/A

Brief Study Title: Temporal Resolution and Speech Perception In Noise of adults with and without HIV.

Study Number: N/A

Site: Infectious Disease Clinic at Steve Biko Academic Hospital

1. I have read and understood item 1.5.5 on page 5 and section 3 (pages 14-20) "Responsibility of the Principal Investigator (PI) and participating investigators of the *Clinical Trials Guidelines of the Department of Health: 2000*

2. I have notified the South African regulatory authority of any aspects of the above guidelines with which I do not / unable to comply (If applicable, this may be attached to this declaration).

3. I have thoroughly read, understood, and critically analysed (in terms of the South African context) the protocol and all applicable accompanying documentation, including the investigator's brochure, patient information leaflet(s) and informed consent forms(s).

4. I will conduct the trial as specified in the protocol.

5. To the best of my knowledge, I have the potential at the site(s) I am responsible for, to recruit the required number of suitable participants within the stipulated time period.

6. I will not commence with my role in the trial before written authorizations from the relevant ethics committee (s) as well as the South African Medicines Control Council (MCC) have been obtained.

7. I will obtain informed consent from all participants or if they are not legally competent, from their legal representatives.

8. I will ensure that every participant (or other involved persons, such as relatives), shall at all times be treated in a dignified manner and with respect.

9. Using the broad definition of conflict of interest below, I declare that I have no financial or personal relationship(s) which may inappropriately influence me in carrying out this clinical trial.

   *Conflict of interest exists when an investigator (or the investigator's institution), has financial or personal relationships with other persons or organizations that inappropriately influence(bias) his other actions)**

   *Modified from: Davidhoff F, et al. Sponsorship, Authorship and Accountability.

   (Editorial) JAMA Volume 286 number 10 (September 12, 2001)

10. I have not previously been involved in a trial which has been closed due to failure to comply with Good Clinical Practice.

11. I have not previously been the principal investigator at a site which has been closed due to failure to comply with Good Clinical Practise (*Attach details)

12. I will submit all required reports within the stipulated time-frames.

Signature:____  _____ Date:18/01/2019

Witness:  _____ Date:18/01/2019

RESEARCHER DECLARATION

APPLICATIONS MUST INCLUDE THE FOLLOWING STATEMENTS

Hereby I, Michaela Juliana Wantenaar in my capacity as principle researcher, that

1 Research subjects will be informed, information will be handled confidentially, research subjects reserve the right to choose whether to participate and, where applicable, written permission will be obtained for the execution of the project (example of permission attached).

2 No conflict of interests or financial benefit, whether for the researcher, company or organization, that could materially affect the outcome of the investigation or jeopardize the name of the university is foreseen.

3 Inspection of the experiments in loco may take place at any time by the committee or its proxy.

4 The information I furnish in the application is correct to the best of my knowledge and that I will abide by the stipulations of the committee as contained in the regulations.

5 Signed:  _____ Date: 18/01/2019

Appendix P

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Department of Speech-Language Pathology and Audiology

PARTICIPANT FEEDBACK LETTER

TEMPORAL RESOLUTION AND SPEECH PERCEPTION IN NOISE OF ADULTS WITH OR WITHOUT HIV

Participant name and surname: _____
Date of assessment: _____
Hospital: _____

Dear Participant,

Thank you for participating in the above-mentioned research study.

The following tests were performed:

Auditory evaluation

Tympanometry

Acoustic Reflex Measurements

Pure tone audiometry

Auditory processing evaluation

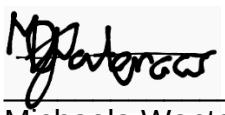
Gaps-In-Noise test (GIN)

Random Gap Detection Test (RGDT)

Digits-In-Noise test (DIN)

Considering the normal test results obtained for the auditory evaluation there is no need for further assessment. It is only recommended to visit an audiologist if you notice a change in your hearing and/or balance.

Kind Regards,



_____
Michaela Wantenaar
(Student Researcher)
082 395 1530

Appendix Q

Title:

Temporal resolution and speech-in-noise abilities of adults with and without HIV.

Authors:

Author – Michaela Wantenaar: B Communication pathology: Audiology, University of Pretoria

Co-author – Prof Lidia Pottas: (PhD) communication pathology, University of Pretoria

Co-author - Prof Maggi Soer: (PhD) communication pathology, University of Pretoria

Co-author – Dr Marien A Graham: (PhD) Department of Science, Mathematics and Technology Education, Faculty of Education, University of Pretoria, Pretoria, South Africa

Corresponding author: Michaela Wantenaar

Address: Department of Speech-Language Pathology and Audiology

University of Pretoria

Hatfield 0028

South Africa

Private Bag X20

Contact details: michaela.wantenaar@gmail.com

Abstract:

This study aimed to compare temporal resolution and speech perception in noise in adults between the ages of 18-40 years old with and without human immunodeficiency virus (HIV) with normal audiometric results. The participants consisted of two groups: an HIV group (n=20), and an age and sex-matched control group (n=20). Pure tone audiometry and acoustic immittance testing was conducted as part of the selection criteria process. Clinical examinations that was carried out included the Random Gap Detection Test (RGDT), Gaps-In-Noise (GIN) test and the Digits-In-Noise (DIN) test. A statistically significant higher occurrence of temporal resolution and speech-in-noise deficits was present in the HIV group compared to the control group. These findings emphasize the importance of monitoring the hearing and central auditory processing function in individuals with HIV to assist in management of these difficulties.

Key words: HIV; Temporal resolution; Speech perception in noise; Gaps-In-Noise (GIN) test; Random Gap Detection Test (RGDT); Digits-In-Noise (DIN) test

Introduction:

The Human Immunodeficiency Virus (HIV) epidemic is now in its third decade and it is proving to be one of the greatest health challenges the world has to face. At the end of 2018, the UNAIDS estimated that there were about 37.9 million people globally infected with HIV and AIDS. Of these numbers, 1.7 million were children younger than 15 years of age. It was also estimated in 2018 that 7.7 million members of the South African population were living with HIV and AIDS, with the prevalence rate of adults between the ages of 18 to 49 years of age at about 20.4% (UNAIDS, 2019).

Infection with HIV leads to the advancement of Acquired Immunodeficiency Syndrome (AIDS) (HIV.gov, 2017). HIV is a virus that invades the body's immune system by infecting the CD4 cells (also known as T cells). It infects the body and destroys these cells that adapt the functioning of the immune system, leading to the exhaustion of bodily defences and advancing the occurrence of an array of diseases labelled opportunistic infections (Quidicomo & Matas, 2013).

The high prevalence of HIV has also placed a heavy burden on the provision of audiological healthcare services in South Africa (Swanepoel, 2006), due to the fact that the precise occurrence and mechanisms of auditory dysfunction create difficulties in the assessment, monitoring and treatment of individuals (Kallail, Downs, & Scherz, 2008). Past research and discussions focussed mostly on the mortality rate due to HIV (UNAIDS, WHO, & UNOHCHR, 2009). It is essential, however, to also consider the impact that this virus has on the national costs of medical care, and the implications for society, such as the probable loss of a productive work force as well as the quality of life of these individuals (UNAIDS, WHO, & UNOHCHR, 2009).

The term "quality of life" can refer to the experience a person has of his or her own life as well as to the person's actual living conditions. With reference to people living with HIV and AIDS, quality of life has been defined as the awareness of an individual when it comes to his/her position in life (Wig, Lekshmi, Hemraj, Ahuja, Mittal, & Agarwal, 2006). HIV has a negative impact on the psychosocial, spiritual, and emotional well-being of an individual. Furthermore, this virus has possible biomedical consequences including disorders of the auditory system, which may lead to an overall decrease in quality of life (Mngadi, 2003). A disorder of the auditory system, such as a hearing loss, is only one of the many effects that the HIV virus may have on the human body.

Central nervous system (CNS) damage can be a devastating consequence of HIV infection, with a major impact on quality of life (Zhan, Fellows, Qi, Clavier, Soli, Shi et al., 2018). This highlights the importance of early treatment by healthcare professionals to avert and decrease the detrimental effects that this virus has on the individual and his/her quality of life.

The HIV virus may influence various aspects of the auditory system, and the effects can be divided into three main groups. Firstly, hearing can be directly affected by the HIV virus, as it can affect the peripheral and central neural pathways involved in hearing (Maro, Moshi, Clavier, MacKenzie, Kline-Schroder, Wilbur et al., 2014). Secondly, it may indirectly affect the auditory system through the development of infections such as otitis media, which can cause a conductive hearing loss. Otitis media is common amongst individuals with HIV due to the immunocompromised state leading to more infections (Maro et al., 2014). Finally, it may cause a sensorineural hearing loss, mainly because of the potentially ototoxic medications which are used for treatment of other life-threating infections such as anti-tuberculous or anti-retroviral medication (Maro et al., 2014).

Based on the magnetic resonance imaging (MRI) findings in a study by Zhan et al. (2017), it is reasonable to assume that individuals with HIV could possibly have central auditory processing (CAP) deficits. Since HIV infection can damage central auditory pathways, central auditory tests could be useful to track or diagnose central nervous system effects of HIV. Furthermore, it can also be assumed that CAP deficits will correlate to the cognitive deficits in HIV patients, which means that central auditory tests may provide a new way to assess CNS function in individuals with HIV (Zhan et al., 2017). Further extensive research proposes that not only does HIV affect peripheral hearing, but that individuals with HIV have been shown to struggle to comprehend speech-in-noise (Luque, Orlando, Leong, Allen, Guido, Yang, & Wu, 2014). Speech perception in noise is a cognitively challenging task which links to central auditory processing. Torre and colleagues (2016) investigated the speech audiometric results of individuals with and without HIV, by comparing various speech audiometric measures for the two groups of participants. However, since the tests were conducted in a quiet environment with a moderately increased presentation level, they caused a ceiling effect and proved to be too easy for the participants. A more complex listening task should be presented to provide a better clinical perspective on

the evaluation of the effect that HIV has on speech communication. It is recommended that such complex listening tasks should include speech-in-noise testing.

An essential skill of auditory processing, linked to speech perception in noise, is temporal processing, which is the awareness of sound in a constrained or definite interval field (Geffner & Ross-Swain, 2007). This processing ability is a precondition for comprehending speech in background noise as well as in quiet conditions, as speech sounds fluctuate over time. Of importance for the current research project is temporal resolution, which denotes a temporal processing task used in the comprehension of quick altering acoustic signals and is essential for defining momentary changes in the intensity of background noise, a skill that is of vital importance for speech acoustic perception.

Previous studies have shown a link between the perception of speech-in-noise and temporal resolution deficits (determined by gap detection in the older population) as well as gap detection thresholds (Harris, Eckert, Ahlstrom, & Dubno, 2010).

In order for hearing care professionals to appropriately evaluate, treat, manage, and monitor individuals with HIV, an increasing amount of evidence-based information is needed on the occurrence and mechanisms of auditory dysfunction in these specific individuals. Further research should focus on the processes of auditory neural functioning and central auditory processing, and should include speech perception in noise tests. More complex listening tasks should be conducted as there is limited research relating to speech perception and speech-in-noise abilities of individuals with HIV (Torre et al., 2016). Most research regarding hearing functions of individuals with HIV has focused on peripheral hearing loss, with limited research reporting on auditory processing. Even though research evidence of central auditory deficits has been described, most of the previous research did not focus on a specific auditory processing skill but rather on the integrity of the auditory pathway (Dawood, Klop, Olivier, Elliott, & Pillay, 2019). The aim of the current study is therefore to determine the temporal resolution skills and speech perception in noise of adults with and without HIV.

Materials and Method

The Research and Ethics Review Committee of the University of Pretoria (approval no: HUM019/0119) and a tertiary referral hospital (approval no: GP_201905_012)

approved the current study. A descriptive cross-sectional comparative research design was employed. This study made use of convenience sampling to recruit participants. A quantitative applied research approach was followed. Each participant provided written informed consent to participate in the study.

Participants:

The participants consisted of two groups: an HIV group (n=20), and a healthy age and sex-matched control group without HIV (n=20). The HIV participants were recruited from a tertiary hospital in South Africa. The hospital authorities provided written permission to access the medical records, which contained information pertaining to CD4 cell counts. Participants of the control group were voluntary participants sampled at a healthcare clinic that had undergone a voluntary HIV screening test. In order to minimize the possible effect that age has on hearing as well as auditory processing, only participants below the age of 40 years were allowed to participate in the study.

Audiological examination:

Participants had to present with normal peripheral hearing, as well as normal acoustic immittance measurement results as it is a prerequisite for reliable central auditory processing testing. Tympanometry was performed using a diagnostic Y-226 Hz probe tone (GSI TympStar™, Grason Stadler). The following criteria were used for normal adult acoustic admittance profiling: ear canal volume, 0.8 to 2.0 ml; compliance, 0.3 to 1.8 ml; and middle ear pressure, −50 to +50 (Martin & Clark, 2006). Furthermore, participants had to present with ipsilateral reflexes at 1000 Hz from 70 to 95 dBHL (Kramer, 2014). Automatic diagnostic air conduction (AC) pure tone audiometric testing was performed to determine whether the participant presented with normal hearing. The Interacoustics AT235h audiometer / WelchAllyn GSI 61 clinical audiometer was used. The participants were seated in a soundproof booth and they had to press a button when they heard a sound presented through earphones to test air-conduction thresholds. Air conduction testing was conducted at 125Hz-8000Hz. A threshold was established when the participant responded to the presented tone 50% of the time. Results were deemed normal when air and bone conduction thresholds were ≤ 15 dBHL.

Temporal resolution assessment:

Temporal resolution abilities were evaluated using the Random Gap Detection Test (RGDT) and the Gaps-In-Noise (GIN) test. The Sansui CD210 CD player and CD's from Auditec and Telephonic -50 earphones had been used for the GIN test and RGDT.

For the procedure of the RDGT, the number of tones or clicks heard had to be counted by the listener, with options being one or two tones or clicks. The listener had to provide a verbal or non-verbal response (Chermak & Lee, 2005). Gap detection thresholds >20 milliseconds were described as abnormal and a temporal processing disorder was present (Keith, 2003). The GIN test was presented monaurally and the participants were instructed to push a response button as soon as they perceived a gap in between the noise. The shortest interval detected in four of the six presentations is known as the gap detection threshold, which can be used to identify central auditory nervous system lesions. Results obtained from the GIN test were considered abnormal when the gap detection threshold >6 msec and the calculated percentage (the number of correct responses) was lower than 54% indicating that a temporal processing disorder was present (Paulovicks, 2008).

Speech perception in noise assessment:

The Digits-In-Noise (DIN) test evaluated the speech perception in noise abilities, and a Samsung smartphone with telephonic -50 earphones was used. The DIN test was conducted by presenting three digits ranging from 0 to 9 in background noise, through headphones on a smart phone. Once the three digits have been presented, a screen pop-upped where the listener had to type what they heard. Even if it was not possible to identify all three numbers, they had to type in three numbers to be able to continue to the next one. Twenty-three, three-digits stimuli were presented. Once the test had been completed, the results were depicted as a signal-to-noise ratio (SNR). Expected results had to be -8 SNR. A SNR lower than -8 was considered to be abnormal test results, indicating that the listener struggled to hear speech in the presence of background noise (Potgieter et al., 2016).

Data analysis:

For the purpose of this study, data collection sheets were created in order to record all the test results from the participants in the control and HIV groups (Appendix M). By coding and editing data it was possible to analyse the data using the IBM Statistical

Package for Social Sciences (SPSS version 22) statistical programme. The data were adapted into numerical format and stored on a Microsoft Excel sheet and introduced for analysis to the statistical programme and by applying a repeated measure analysis of various variables. Different statistical methods were used by the biostatistician (Appendix N) to analyse the data. This included descriptive statistics. Depending on the distribution of the data such as median, standard deviation, 25th and 75th percentiles, percentages and numbers were used to describe the data. Subsequently, to test for differences between two independent groups (e.g. different participants in the control group and the HIV group), the Mann-Whitney test was used (Morgan, Leech, Gloeckner, & Barrett, 2013). A p-value of <0.05 was considered to be statistically significant. On the other hand, if the p-value was >0.05, the differences between the groups were not considered to be statistically significant (Morgan, Leech, Gloeckner, & Barrett, 2013). Graphs, tables, and figures were used to deliver a more adequate way of depicting and representing the data.

Results:

Demographic features of the participants are shown in Table I.

Table I Demographic features of both groups of participants

	All (n=40)	**HIV group (n=20)**	**Control group (n=20)**	***P value***
Age (Years)	29.18 (±7.2)	29.45 (±7.7)	28.90 (±6.9)	0.583
Gender (%)				
Male	14 (35%)	7 (35%)	7 (35%)	-
Female	26 (65%)	13 (65%)	13 (65%)	-

± = Standard Deviation, %= Percentage, *p≤0.05 statistically significant.

The mean age of the two groups was very similar (HIV group: 29.4 years, ±7.7, range 20 to 40; control group: 28.9 years, ±6.9, range 20 to 39) with no statistically significant difference between the two study groups (p=0.583; Independent Sample T test). The researcher allowed a two-year age difference between the age of the HIV participants and their age-matched control participants, due to the difficulty in finding exact age matches between the HIV and control group. An equal number of male and female participants was tested for both groups, 14 males (35%) and 26 females (65%).

The comparisons between male and female participants of both groups for each test appear in Tables II and III.

Table II. Comparison of male and female participants in the control group

Control group

	Male (n=7)				Female (n=13)				p-value
	Min	Max	Mean	SD	Min	Max	Mean	SD	
DIN: SNR	-12.60	-10.00	-11.65	0.92	-12.20	-10.60	-11.44	0.56	0.354
GIN: GD Threshold Right ear (ms)	5	6	5.71	0.48	3	6	5.23	1.01	0.388
GIN: GD Threshold Left ear (ms)	5	6	5.43	0.53	4	6	5.38	0.76	1.000
GIN: Total score in %	63	75	67.57	4.75	61	85	69.69	7.45	0.740
RGDT: 500 Hz (ms)	2	10	5.29	2.36	2	15	6.69	3.49	0.429
RGDT: 1000 Hz (ms)	2	15	5.43	5.15	2	5	3.85	1.51	1.000
RGDT: 2000 Hz (ms)	2	10	7.00	3.87	0	10	5.46	3.52	0.414
RGDT: 4000 Hz (ms)	2	10	4.86	2.67	0	10	4.62	3.45	0.711
RGDT: Click (ms)	2	10	6.71	3.25	2	10	6.23	3.32	0.855

*$p \leq 0.05$ statistically significant

The results detailed in Table II reveal that there was no statistically significant difference between male and female participants for any of the tests. The comparison between male and female participants in the HIV group is depicted in Table III.

Table III. Comparison of male and female participants for HIV group

HIV group									
	Male (n=7)				Female (n=13)				p-value
	Min	Max	Mean	SD	Min	Max	Mean	SD	
DIN: SNR	-11.20	-9.20	-10.54	0.75	-12.20	-4.40	-10.12	2.05	0.804
GIN: GD Threshold Right ear (ms)	8	10	9.14	1.06	8	10	9.54	0.87	0.613
GIN: GD Threshold Left ear (ms)	8	12	10.00	1.63	8	12	9.69	1.10	0.722
GIN: Total score in %	34	53	44.71	6.67	39	49	44.54	3.282	0.954
RGDT: 500 Hz (ms)	5	20	10.00	5.77	10	30	17.69	6.95	0.026

RGDT: 1000 Hz (ms)	5	25	16.43	7.48	5	40	15.77	9.32	0.664
RGDT: 2000 Hz (ms)	5	40	17.14	11.12	5	30	16.92	7.51	0.604
RGDT: 4000 Hz (ms)	10	40	18.57	9.88	5	30	15.00	6.12	0.437
RGDT: Click (ms)	10	30	17.14	6.36	10	20	14.62	4.77	0.423

*$p \leq 0.05$ statistically significant

Table III indicates that there were no statistically significant differences between male and female participants in any of the tests. As there were no discrepancies found between male and female participants in either of the participant groups, no distinction will be made between male and female for the rest of the discussion.

The results for the RGDT, specifically the gap detection threshold results obtained for each participant group, are depicted in Table IV.

The gap detection threshold, the shortest gap duration where the participant perceived two tones, was determined for each frequency, 500Hz to 4000 Hz, and a click stimulus. The approximate gap detection threshold was calculated (RGDTh) once the gap detection values for each frequency had been determined. Descriptive statistics of the RGDT results obtained for both groups are displayed in Table IV with the calculated *p*-values to compare the two groups.

Table IV. The approximate (RGDTh) of the control and HIV group

Group	**Control group (n=20)**				**HIV group (n=20)**				**P value**
Frequencies	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Mann-Whitney U test**
500 Hz	2	15	6.20	3.15	5	30	17.50	8.66	<0.001*
1000 Hz	2	15	4.40	3.23	5	30	15.00	7.43	<0.001*
2000 Hz	0	10	6.00	3.62	5	40	16.00	8.52	<0.001*
4000 Hz	0	10	4.70	3.13	5	40	17.00	8.64	<0.001*
Click	2	10	6.40	3.21	10	30	15.50	5.35	<0.001*
RGDT_Th			5.32	2.13			16.06	5.66	<0.001*

*$p \leq 0.05$ statistically significant

A significant difference in the approximate RGDTh was found between the participants in the control group and the participants in the HIV group for all the frequencies tested as well as for the click stimulus. The mean random gap detection threshold (RGDT_Th) calculated for the control group (5.32 ms) was within the normal limits of <8 ms, while the mean RGDT_Th (16.06 ms) of the HIV group fell outside the norm.

The difference between the calculated p-values for the mean RGDT_Th of the performance of the control and HIV group was statistically significant ($p<0.001$).

The GIN test consisted of two parameters namely the total percentage of correct responses and the gap detection threshold (GDTh). The differences between left and right ears in each participant group are firstly reported and then the results of the two parameters are displayed.

The gap detection thresholds (GDTh) (in ms) for the left and right ears of both groups of participants are displayed in Table V.

Table V. GIN: GDTh's (in ms) in left and right ear

Group	Ear	Mean	SD	25th percentile	50th percentile	75th percentile	P value Wilcoxon matched pairs test
HIV (n=20)	Right Left	9.40 9.80	0.94 1.28	8.00 8.50	10.00 10.00	10.00 10.00	0.248
Control (n=20)	Right Left	5.40 5.40	0.88 0.68	5.00 5.00	6.00 5.50	6.00 6.00	1.000

*$p\leq0.05$ statistically significant

The results in Table V indicate that, for the HIV group, the mean GDTh of the left ear was 9.80 ms and the mean GDTh for the right ear was 9.40 ms. Better GDTh's per ear were displayed in the control group (mean GDTh 5.40 ms for the left ear and 5.40 ms for the right ear). Nevertheless, it is clear from Table V that no statistically significant difference was obtained between the left and right ears within either the control (p=1.000) or the HIV (p=0.248) group. These results are indicative of similarities in response between ears.

The percentage (%) of correct responses for the right and left ear of both groups of participants are displayed in Table VI.

Table VI. GIN: % of correct responses for the left and right ear

Group	Ear	Mean	SD	25th percentile	50th percentile	75th percentile	P value Wilcoxon matched pairs test
HIV (n=20)	Right Left	45.90 43.45	5.379 5.482	43.25 40.50	46.00 44.00	49.50 46.75	0.054
Control (n=20)	Right Left	69.45 68.35	7.373 6.839	63.50 62.25	67.00 67.00	74.50 74.50	0.286

*$p\leq0.05$ statistically significant

The results in Table VI indicate that, for the HIV group, the mean percentage of correct response of the left ear was 43.45% and the mean percentage of correct response for the right ear was 45.90%. Better percentage of correct responses per ear was displayed in the control group (mean % of correct responses was 68.35% for the left ear and 69.45% for the right ear). Nevertheless, it is clear from Table VI that no statistically significant difference was obtained between the left and right ear for either the control (p=0.286) or the HIV (p=0.054) group. These results are indicative of similarities in response between ears.

The total percentage GIN score was calculated by adding the total number of correct responses minus the false positives divided by the total number of gaps (120 for both ears) times 100 to get the total correct percentage. The total percentages for both the control and HIV participant groups are displayed in Table VII.

Table VII. GIN: Total percentages of correct responses

Group	Mean	SD	25th percentile	50th percentile	75th percentile	P value Mann Whitney U test
HIV (n=20)	44.60	4.570	41.25	44.50	47.75	<0.001*
Control (n=20)	68.95	6.581	63.00	66.00	74.50	

*p≤0.05 statistically significant

As shown in Table VII, the mean percentages of correct responses for each gap, across all gaps detected for each test list used, indicated variability between the two participant groups. The mean percentage of correct responses for the participants in the control group (without HIV) was 68.95% with SD 6.58, whereas the mean of correct responses for the participants in the HIV group (44.60%, ±4.57) was 24.35% lower than that of the control group. Overall, the HIV group displayed a poorer performance and a statistically significant difference was found between the participant groups (p<0.001).

The total gap detection thresholds for the left and right ears (40 ears) were calculated for each participant group. These results were obtained as the GIN test is a monaural test and there was no significant difference between the ears. The results were obtained by grouping the results of each ear (in ms's) per group together and then comparing the outcomes.

Table VIII. GIN: Total GD threshold left and right ears (ms)

Group	Mean	SD	25th percentile	50th percentile	75th percentile	P value Mann Whitney U test
HIV (n=20)	9.60	1.12	8.00	10.00	10.00	<0.001*
Control (n=20)	5.40	0.77	5.00	6.00	6.00	

*$p \leq 0.05$ statistically significant

As shown in Table VIII, the mean total GD threshold for the participants in the control group (without HIV) was 5.40 ms with SD 5.00, whereas the mean of correct responses for the participants in the HIV group (9.60 ms ±1.12) was lower than that of the control group. Overall, the HIV group displayed a poorer performance and a statistically significant difference was found between the participant groups (p= <0.001).

3.3 Speech-in-noise testing

The results for the DIN test are displayed in Table IX. Each DIN test consisted of 23 digit triplets to estimate the SNR corresponding to the 50% correct recognition probability.

Table IX. DIN results for the control and HIV group

Group	N	Min	Max	Mean	SD	P value Mann-Whitney U test
HIV	20	-12.2	-4.4	-10.27	1.70	0.002*
Control	20	-12.6	-10.0	-11.5	0.69	

*$p \leq 0.05$ statistically significant

The results in Table IX for the DIN test indicate that the mean SNR for the participants in the control group (without HIV) was -11.5 SNR with SD 0.69, whereas the mean SNR for the participants in the HIV group was -10.27 SNR with SD 1.70 these results indicated a statistically significant difference (p=0.002) between the results of the control group and the HIV group.

Discussion:

The RGDT makes use of a complex stimulus that can be useful to screen temporal resolution (Chermak & Lee, 2005). The p-values of the gap detection thresholds that were evaluated through the RGDT, labelled RGDT_Th, were significantly different for the two participant groups. In the current study a mean RGDT_Th of less than 10 ms

was obtained by the control group. However, a mean RGDT_Th of more than 15 ms was obtained by the HIV group. The poorer performance reported for the HIV group could possibly arise from auditory processing deficits that accompany HIV, which affect specific temporal aspects of audition such as temporal gap detection. A previous magnetic resonance imaging (MRI) study that was done on individuals with HIV found that various parts of the central auditory system including the thalamus and corpus callosum are affected by HIV (Zhan, Buckey, Fellows, & Shi, 2017). Since central auditory processing (CAP) relies on the collaboration of multiple brain areas, the central auditory deficit may correlate with HIV-associated neurocognitive disorders (HAND) (Zhan, Buckey, Fellows, & Shi, 2017). Reports from literature concur that individuals with HIV have abnormal gap detection thresholds (Luque, et al., 2014). The control group had RGDT maximum thresholds of 10 and 15 ms at all the frequencies tested and for the click stimuli, while the maximum thresholds for the HIV group were 30 and 40 ms respectively. Yalcinkaya et al. (2009) propose that if an individual has a RGDT_Th that exceeds 20 ms he/she could possibly have temporal processing deficits. The researcher is of the opinion that the RGDT is a clinically useful tool to evaluate temporal resolution abilities in the HIV population. This processing ability is a precondition for comprehending speech in background noise as well as in quiet conditions, as speech sounds fluctuate over time (Vaidyanath & Yathiraj, 2015).

In the current study the average gap detection thresholds with the GIN test, for the HIV group was higher than that of the control group although both groups presented with normal hearing. The participants in the control group obtained a mean gap detection threshold of 5.40 ms in comparison to the HIV group's 9.60 ms. Normative values were obtained in a study by Musiek et al. (2005) who compared individuals with confirmed CNS involvement to normal-hearing listeners. The normal-hearing participant group obtained a mean gap detection threshold of 4.8 ms to 4.9 ms, whereas the participants with CNS involvement demonstrated a mean gap detection threshold of 7.8 ms to 8.5 ms (Maro et al., 2014). Therefore, it can be assumed that HIV and CNS involvement can lead to poorer temporal resolution abilities and this in turn will lead to difficulties with speech perception in noise.

The current findings are supported by research regarding auditory evoked potentials (AEP) that are used to assess neuro-electrical activity in central auditory pathways. A study by Matas et al. (2009) reported electrophysiological abnormalities in individuals with HIV. These abnormalities mostly concerned cognitive potential and the ABR (Matas, Silva, Marcon, & Goncalves, 2009). It was stated that the abnormalities found during ABR testing were the result of CNS involvement. This is indicative that the brainstem structures as well as the auditory nerve are primary structures that are affected by HIV. The damage to the auditory pathway causes significant loss in the transmission of auditory information (Matas et al.,2009).

Individuals with HIV have shown abnormalities in auditory evoked potentials (AEP) in studies where auditory brainstem response (ABR) testing was done. These abnormalities were consistent with a higher rate of central processing deficits compared to individuals without HIV (Maro, Fellows, Clavier, Gui, Rieke, Wilbur et al., 2016). Pagano et al. (1992) performed an ABR study and reported prolonged ABR latencies in a group of 35 individuals with HIV, a finding which was ascribed to the effects of HIV on the CNS. A similar study was conducted by Matas et al. (2009) where ABR and Auditory Middle Latency Response (AMLR) tests were performed on 56 individuals with HIV, some off (n=24) and on some on Antiretroviral therapy (ART) (n=32). The results showed that the individuals with HIV who were receiving ART had a higher rate of abnormal test results. About 63% of the individuals on ART had abnormal evoked responses, but only 29% of those abnormal responses could be explained by deficits in the peripheral hearing system. Similarly, it has been found that individuals with HIV show a higher percentage of changed brainstem auditory evoked potential (BAEP) that indicates central auditory pathway impairment when compared to individuals without HIV (Matas, Samelli, Angrisani, Magliaro, & Segurado, 2015).

Temporal resolution is important for understanding speech in challenging listening situations as well as in quiet conditions, because all listeners need to determine the duration of speech and silent segments and use temporal cues in order to understand what is being said (Vermeire, Knoop, Boel, Auwers, Schenus, Talaveron-Rodriquez, de Boom, & de Sloovere, 2016). Omidvar et al. (2013) concurred that there is a link between temporal resolution function and speech perception in noise. They found that adequate temporal resolution abilities are essential, since temporal resolution enables

an individual to separate acoustic signals over time, an ability that is critical for speech perception in noise.

Another parameter that was used to assess temporal resolution was the total percentage of correct responses on the GIN test. The current study showed a significant difference of 24.35% regarding the percentage of correct responses between the two participant groups. The total percentage of correct responses was determined with a fail or pass result. For a total percentage of correct response to be considered normal, results have to be ≥54%, for individuals 12 years and older (Musiek et al., 2005). According to Musiek et al. (2005) researchers making use of the GIN test should develop their own norms for the target population being studied. In the current study, the HIV group performed poorly as 20 (100%) participants scored ≤54%, whereas the all the participants in the control group passed this aspect of the GIN test. These results indicated a significant difference between the two participant groups ($p<0.001$, Fisher's Exact test).

A previous study conducted by Musiek et al. (2005) on normal hearing individuals indicated that these participants presented with 70% gap detection responses. Similar findings were found by Samelli and Schochat (2008), as these researchers found that participants with normal hearing presented with an average of 67.25% gap detection responses.

However, a study done on HIV infected individuals did not report on the percentage of correct responses within the HIV group (Maro et al., 2014). This justifies the need for further investigation as the current study found significant differences regarding the percentage of correct responses for the two participant groups. A low percentage in this test could possibly indicate a temporal resolution deficit as the GIN is regarded as a clinically useful test to assess temporal resolution abilities and provide insight into the neural integrity of the CANS (Samelli & Schochat, 2008).

It was anticipated that the HIV group in the current study would perform more poorly than the control group on both sections of the GIN test, including the percentage of correct responses and the gap detection threshold. This prediction was proved

accurate. The researcher is of the opinion that the poorer percentage of correct gap detection responses demonstrated by the HIV group and the statistically significant difference in the mean GDTh ($p<0.001$) between the HIV and control group, could be a leading cause of speech perception in noise deficits, and could possibly be attributed to HIV infection.

When the left and right ears of both participants groups were compared no significant difference was found for either group with regard to the GDTh means. The control group did, however, display better GDTHs than the HIV group. These results correlate with results from previous studies which revealed similar gap detection thresholds for the left and right ears across their study groups (Samelli & Schochat, 2008).

The GIN test could be a clinically valuable tool when used together with other auditory processing tests and speech-in-noise evaluations to further investigate possible processing difficulties. Furthermore, this test should be included in the test battery to evaluate the CANS as it can provide insight into the neural integrity of the CANS (Samelli & Schochat, 2008).

In order to understand speech, a listener must be able to resolve specific temporal cues, including duration of speech segments and silent intervals as well as quick modulation of intensity (Vermeire et al., 2016).

Helfer and Vargo (2009) conducted a study on a normal hearing middle-aged woman and reported that there was no correlation between temporal resolution and speech recognition in the presence of steady-state background noise (quiet). However, when the test was presented with a competing speech situation (speech-in-noise), a correlation was found between temporal resolution and speech recognition (Helfer & Vargo, 2009). They concluded that to successfully determine whether an individual has a deficit in temporal resolution a speech masker or modulated noise should be used (Helfer & Vargo, 2009). Similarly, Torre et al. (2016) conducted a research study to evaluate the speech audiometric findings in individuals with HIV. They found that among individuals with HIV and HIV related variables (HIV viral load and CD4 cell count) there were no significant findings associated with either word recognition scores or speech recognition threshold (SRT). However, a ceiling effect was present because the tests were conducted in quiet conditions with a relatively high presentation level.

Due to this, the researchers suggested that a more complex listening task, such as speech-in-noise testing, would be a more useful test to evaluate the effects of HIV on speech communication.

A common complaint in individuals with HIV is that they have difficulty understanding speech in noise. This was also seen in a study by Maro et al. (2014). Individuals receiving treatment for HIV through ART's reported difficulties in understanding speech-in-noise. Another study was done to assess the speech-in-noise perception as a marker of cognitive impairment in individuals with HIV. However, a weakness in the previous study was that the researchers did not make use of direct measurements to determine these specific individuals' speech-in-noise perception, but rather collected data through self-report (Zhan et al., 2018). In the current study the speech-in-noise perception was measured through the DIN test as well as self-report. The control group had a mean of -11.5 SNR, whereas the HIV group obtained a mean of -10.27 SNR, a significant difference. HIV is known to damage structures of the central auditory system, which can lead to central auditory processing (CAP) deficits. These deficits usually present as difficulty in understanding speech in noise (Zhan, Buckey, Fellows, & Shi, 2017).

Conclusion:

A statistically significant difference was found for the RGDT and GIN test that evaluated temporal resolution abilities between both groups of participants. This was evidenced by the gap detection thresholds that was measured for the RGDT and GIN test. The control group had RGDT maximum thresholds of 10 and 15 ms at all the frequencies tested and for the click stimuli, while the maximum thresholds for the HIV group were 30 and 40 ms respectively. The participants in the control group obtained a mean gap detection threshold of 5.40 ms in comparison to the HIV group's 9.60 ms. In addition, a significant difference was found with the DIN test for both the participant groups in the results of the SNR. It can therefore be concluded that individuals with HIV may present with temporal resolution deficits which could contribute to speech-in-noise difficulties. However, a greater understanding of the effect that HIV has on central auditory processing is not fully known yet. Therefore, additional research can shed light on the extended influence that HIV holds since its prevalence continues to increase worldwide.

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