Evaluation of the olivocochlear efferent reflex strength in the susceptibility to noise-induced hearing loss

Author: **Jomari Veenstra**

A dissertation submitted in fulfilment of the requirements for the degree

M. Communication Pathology (Audiology)

in the Department of Speech-Language Pathology and Audiology

University of Pretoria

Faculty of Humanities

Supervisor: **Prof. Maggi Soer**

2021

Acknowledgments

I would firstly like to thank my supervisor Prof Maggi Soer for sticking with me from the start and guiding me through the process. Thank you for all the time spent reading through my research and making suggestions.

I would like to thank Dr Elize de Koker, Hannah Keppler and Prof Bart Vinck for all the input and suggestions they contributed to my dissertation.

A big thank you to Marien Graham for the statistical analysis.

I would like to thank Nolwazi, Johan and Noise Clippers for arranging the time for me to use the equipment needed to collect data.

I would furthermore like to thank my language editor Dr Elsie Naude.

And lastly but most importantly thank you to all staff members at the Occupational Health Centre of the mine where research was conducted who assisted in the identification of participants and translation.

Abstract

The study aimed to determine the relationship between the medial olivocochlear (MOC) efferent reflex strength and susceptibility to noise-induced hearing loss (NIHL). This was evaluated by measuring the efferent suppression (ES) results from the contralateral suppression of Transient Evoked Otoacoustic Emissions (TEOAEs). It was predicted by several researchers that the strength of the MOC efferent reflex could determine the susceptibility to hearing loss (HL). The prediction was that an individual with a stronger MOC efferent reflex was less susceptible to developing a HL and an individual with a weaker MOC efferent reflex was more susceptible to developing a HL.

The design used in the study was a categorical independent comparative design. The independent values used in the study were the results from the contralateral suppression of the TEOAEs and the thresholds obtained from each participant's pure tone audiogram. A quantitative research approach was used as different numerical values were collected from each participant. The numerical results obtained for each participant were objectively compared between the two identified groups.

Forty-one participants between the ages of 30 and 45 years, who had been exposed to noise levels between 89.3 dBA and 101.6 dBA at a Platinum mine in the North West Province, were used for the study. Twenty participants presented thresholds within normal limits of 0 to 15 dB and 21 participants presented with a permanent minimal NIHL with thresholds of 16 to 40 dB at 3000 Hz, 4000 Hz and 6000 Hz averaged. The data was analysed using the Statistical Package for the Social Sciences (SPSS) program version 25 (IBM Inc.). Non-parametric tests were used with the Mann-Whitney U test, where the ES of the two independent groups were compared.

The results showed no statistically significant difference in the ES of the normal hearing participants compared to the participants with a minimal HL. However, participants with normal hearing presented, on average, with a slightly stronger ES than the participants with a minimal HL. The lowest p-values in this study were calculated at 2000 Hz and 4000 Hz, with a p-value of 0.085 at 4000 Hz for the age category 30 to 35 years and a p-value of 0.086 at 2000 Hz for the age category 41 to 45 years. This suggests that it could be possible that the MOC reflex strength may predict the degree of HL. It is recommended that more research be done on contralateral suppression of TEOAE measurements on participants who present with permanent NIHL to possibly use the MOC reflex to predict susceptibility to HL in clinical practice.

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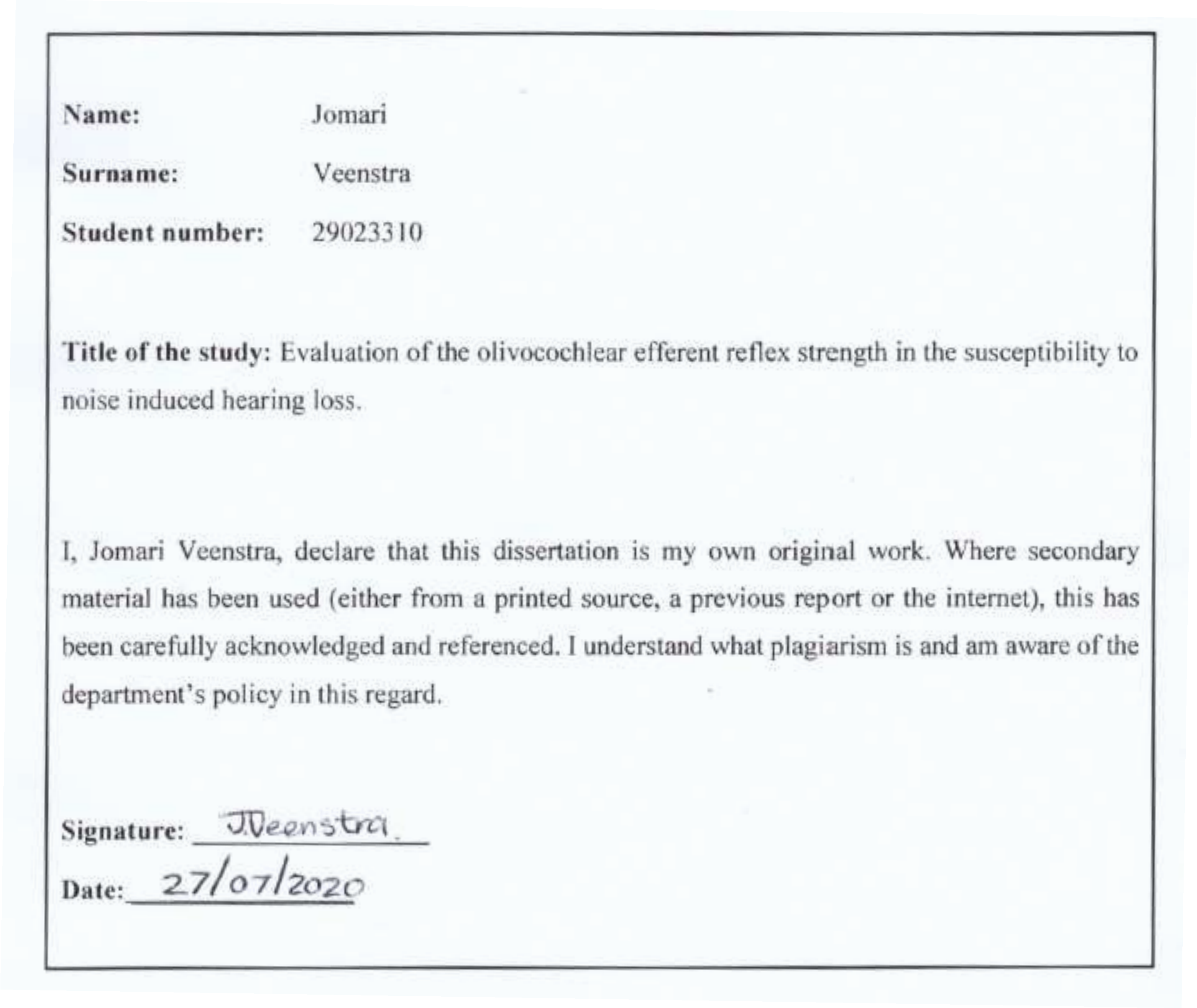
Declaration



Name: Jomari

Surname: Veenstra

Student number: 29023310

Title of the study: Evaluation of the olivocochlear efferent reflex strength in the susceptibility to noise induced hearing loss.

I, Jomari Veenstra, declare that this dissertation is my own original work. Where secondary material has been used (either from a printed source, a previous report or the internet), this has been carefully acknowledged and referenced. I understand what plagiarism is and am aware of the department's policy in this regard.

Signature: JVeenstra

Date: 27/07/2020

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List of abbreviations

ASSR or ASSRs	-	Auditory Steady State Response(s)
dB	-	Decibel
dBA	-	A-weighted decibel
dBpeSPL	-	Decibel peak equivalent sound pressure level
DPOAE or DPOAEs	-	Distortion Product Otoacoustic Emission(s)
ES	-	Efferent suppression
HCP or HCPs	-	Hearing conservation programme(s)
HL	-	Hearing loss
Hz	-	Hertz
MEMR	-	Middle ear muscle reflex
MOC	-	Medial olivocochlear
mPa	-	Milli-pascals
NIHL	-	Noise induced hearing loss
OAE or OAEs	-	Otoacoustic emission(s)
OHC or OHCs	-	Outer hair cell(s)
PTS	-	Permanent threshold shift
RDO or RDOs	-	Rock drill operator(s)
SAP	-	Systems, Applications and Products
SFOAE or SFOAEs	-	Stimulus Frequency Otoacoustic Emission(s)
SNR	-	Signal to noise ratio
SPL	-	Sound pressure level
SPSS	-	Statistical Package for the Social Sciences
SSOAE or SSOAEs	-	Synchronized spontaneous otoacoustic emission(s)

TEOAE or TEOAEs	-	Transient Evoked Otoacoustic Emission(s)
TTS	-	Temporary threshold shift
μs	-	Microsecond
WHO	-	World Health Organisation

Formatting: For the dissertation the APA referencing style was used

1. Chapter 1: Introduction and rationale

1.1. Introduction

Noise-induced hearing loss (NIHL) is the most common occupational disease reported (Begley, 2006) and is the second most common cause of permanent hearing loss (HL) worldwide after age-related HL (Wong et al., 2013). In contrast to age-related HL, NIHL can be prevented (Wong et al., 2013). NIHL is characterised as a sensorineural HL that gradually develops over several years of consistent exposure to noise and is characterised by an audiometric notch at 4000 to 6000 Hz (Katz et al**.,** 2015). According to the Centers for Disease Control and Prevention (CDC), it is estimated that 12.5% of the US population under the age of 19 years' experience NIHL, and an estimated 17 % of the US population between the ages 20 and 69 experience NIHL (CDC, 2020). There are no recent statistics available for NIHL in South Africa, however in 2005 is was estimated that 18% of all documented adult-onset hearing loss cases in the Southern African region were as a result of NIHL (Nelson et al., 2005).

Audiologists working in the fields of industrial and clinical audiology have observed that the audiometric results of employees working in the same noise exposed environment for the same duration of years revealed different degrees of HL. A number of biological or genetic factors that contribute to the susceptibility to HL have been identified in previous studies. These factors include high blood pressure, cholesterol, gender, age, and eye colour (Pyykkö et al., 2009; Henderson et al., 2001). However, if these influencing biological variables that could cause variance in HL are minimised or isolated (controlled for) and the intensity and duration of noise exposure are the same for all individuals, then employees exposed to the same intensity and duration of noise exposure should present with the same degree of HL. One variable that may cause differences in measured HL is the medial olivocochlear (MOC) efferent reflex. The various roles and functions of the MOC reflex includes to improve signal to noise ratio and auditory selective attention (Smith & Keil, 2015), to regulate the dynamic range of hearing (Guinan, 2011), and is primarily responsible for the protection of the cochlea against acoustic trauma (Mertes, 2014).

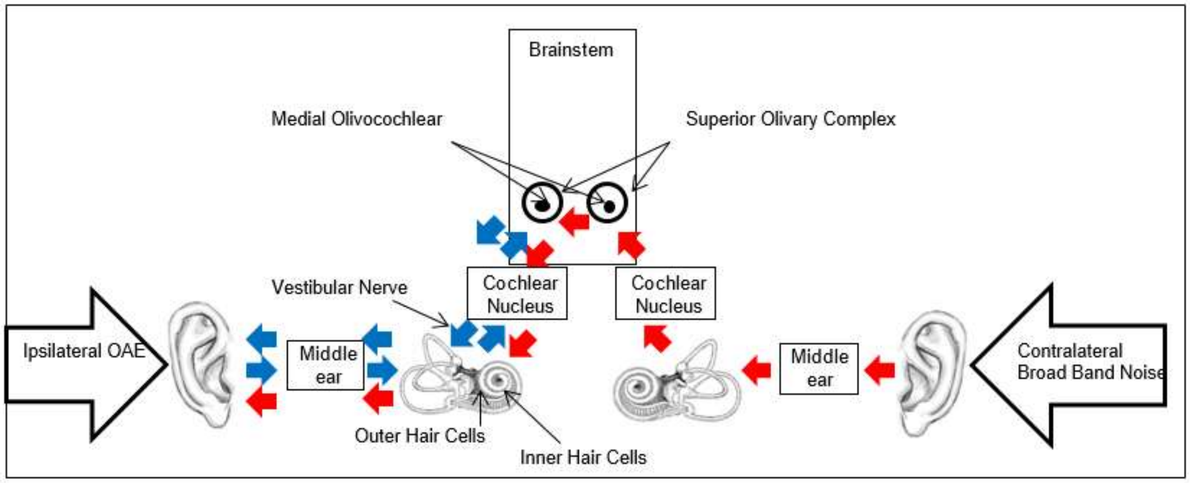

Figure 1: Ipsilateral and contralateral otoacoustic emission (OAE) pathways (Rodgers, 2014)

The ipsilateral and contralateral otoacoustic emission (OAE) pathways are demonstrated in Figure 1. The MOC complex is situated in the medial part of the superior olivary complex of the brainstem and is the final part of the acoustic reflex. The MOC fibres travel to the cochlea through the vestibular nerve to activate the outer hair cells (OHCs) (Guinan, 2006). The MOC reflex can be activated through sound stimulation (Guinan, 2010). MOC activity can be activated and measured by OAEs. The presentation of sound in the ear causes cochlear irregularity or movement of the OHCs stimulating the MOC activity and thus generating emissions that can be measured, in the form of an OAE (Guinan, 2006). This study aimed to investigate if the psychological factor, the MOC efferent reflex, could influence susceptibility to NIHL due to excessive noise exposure.

An OAE test is an objective test used to measure the functioning of the OHCs and is a non-invasive method to measure the functioning of the olivocochlear efferent system (Kemp, 2002). HL caused by excessive noise exposure primarily damages the OHCs. The activation of OHCs is controlled by the medial cochlear efferent system (Lalaki, 2005). The most direct way of measuring the efficacy of the medial cochlear efferent system is to stimulate the contralateral ear with sound (Guinan, 2006). The contralateral MOC reflex is stimulated by the medial cochlear efferent system. MOC induced reductions or decreases of the acoustic output or sound are termed suppression of OAEs (Guinan, 2010) and are mediated through the efferent system by decreasing the amplitude of the OAE that is elicited through stimulation of the contralateral ear (Stuart & Cobb, 2015). Therefore, by applying contralateral stimulation to the MOC efferent auditory system, the efferent suppression (ES) of the OAE can be measured. Contralateral suppression is more commonly measured by using Transient Evoked OAEs (TEOAEs) (Kemp, 2002). TEOAEs are evoked by clicks or tone bursts (Wolter et al., 2012). The strength of the MOC reflex is then measured after contralateral acoustic stimulation with TEOAEs (Keppler et al., 2014).

The link between HL and the strength of suppression of the OAE amplitude with contralateral noise was first investigated in a number of animal studies. These invasive studies indicated that after noise exposure the permanent threshold shift (PTS) showed the greatest change in the MOC system (Kujawa & Liberman, 1997; Zheng et al., 1997A; Zheng et al., 1997B; Zheng et al., 2000). Maison and Liberman (2000) found that the strength of the MOC efferent reflex of animals correlated with the degree of HL and concluded that this measure might, therefore, provide a method of measurement for testing the susceptibility to NIHL non-invasively in humans.

1.2. Rationale

Hearing protection devices have been designed to protect hearing and to minimise the effects of noise exposure. According to the regulations of the Mine Health and Safety Act (Mine Health and Safety Act, MHSA, Act 29 of 1996), it is compulsory for workers to wear hearing protection within the context of a hearing conservation programme (HCP) (SANS 10083, 2013). When properly selected and used, hearing protection devices can be a powerful tool for preventing NIHL. However, regardless of hearing protection and the implementation of HCPs, some workers who present with characteristics of NIHL are still identified. The ideal method for the mining industry to decrease the number of compensation claims submitted yearly would be to identify all the individuals who are more susceptible to developing a HL before they start working in a noisy environment. Ideally, a more stringent HCP should be implemented for those individuals who are more prone to developing a HL. This could include early intervention programmes for the identified individuals before noise exposure occurs, in order to prevent NIHL. Early intervention programmes are compulsory according to the Mine Health and Safety legislation as part of a medical surveillance programme to identify workers at risk of developing a NIHL (Mine Health and Safety Act, MHSA, Act 29 of 1996). One method with the potential to be used in an early intervention programme is measuring the MOC reflex (Keppler et al., 2014; De Souza Alcaras et al., 2013; Otsuka et al., 2016. Using the MOC reflex measurements for predicting possible NIHL is not current practice in early intervention programmes for the reason that there is insufficient data to support such a procedure. It is evident that more research is needed to investigate the feasibility of using the MOC reflex as a prediction of NIHL.

2. Chapter 2: Literature review and problem statement

2.1. Literature review

Numerous studies have been conducted in the past 20 years on the topic of the MOC reflex strength in humans (Aguilar et al., 2014; Brashears et al., 2003; De Souza Alcarás et al., 2013; Hood et al., 1996; Keppler et al., 2014; Kumar et al., 2013A; Kumar et al., 2013B; Marshall et al., 2009; Lichtenhan et al., 2016; Lapsley Miller et al.,, 2006; Mertes & Goodman, 2016; Backus & Guinan, 2007; Mishra & Lutman, 2014; Otsuka et al., 2016; Seixas et al., 2012; Sliwinska-Kowalska & Kotylo, 2002; Wolpert et al., 2014). These studies used various OAE measurements to assess the MOC reflex, namely TEOAEs, Distortion Product OAEs (DPOAEs) and Stimulus Frequency OAEs (SFOAEs), with and without contralateral broadband noise, in different situations and with different participant groups. Some studies included participants with normal hearing, and some participants with temporary or permanent NIHL. Different themes have been investigated regarding the functioning of the MOC, from predicting NIHL to predicting learning disabilities. Not all authors found statistically significant results to confirm their predictions, but all have suggested that more research should be done with these techniques using stringent inclusion and exclusion criteria with specified testing parameters.

Research by Wolpert et al., (2014) demonstrated that MOC activity could protect the cochlea from noise damage in humans. The study was conducted by inducing controlled temporary threshold shift (TTS) in a laboratory setting with 40 normal-hearing participants. The contralateral suppression of DPOAEs was measured and compared to the TTS of each participant. The measurements showed a statistically significant correlation between the TTS and the contralateral suppression of OAEs. It was suggested that more research should be done on the functioning of the MOC reflex in participants with permanent HL. Suggestions for future research recommended by Wolpert et al., (2014) were modified contralateral suppression paradigms, longitudinal group studies, and monitoring lateral efferent effects in humans.

Individuals who had been exposed to noise were studied by De Souza Alcarás et al., (2013), who analysed the results from suppression of DPOAEs and TEOAEs in 55 participants with normal hearing thresholds. Twenty-five of the participants had been exposed to occupational noise and pesticides and were compared to 30 participants with no previous history of noise exposure or exposure to pesticides. The researchers found that the group who had normal hearing thresholds with exposure to noise presented with lower suppression effects than the group who had normal hearing thresholds with no exposure to noise. The results thus confirmed that the MOC reflex was reduced in the group who had been exposed to noise.

The TTS was also researched in a more recent study by Otsuka et al., (2016) to measure the MOC reflex of violin students who were regularly exposed to intense violin sounds in the left ear during their routine instrument practice. Audiometric pure-tone testing and click-evoked OAE testing were performed before and after one hour of noise exposure. TTS measurements before and after the noise exposure were compared. The results indicated that the MOC reflex strength could predict the degree of the TTS and click-evoked OAE reduction. The results were only significant for the ipsilateral MOC reflex, however, and not for the contralateral MOC reflex. It should be noted that only musicians were used for the study of Otsuka et al., (2016). In another study by Brashears et al., (2003), the MOC ES strength in classical musicians and non-musician participants was compared. The researchers found that a more significant binaural contralateral suppression was recorded for musicians than for the non-musician participants. The authors suggested that music could be used to strengthen the auditory pathways influencing the MOC reflex arc as a sound conditioning stimulus. The findings and conclusions of Otsuka et al., (2016) cannot be used for the general population in clinical practice but does confirm that more research regarding the relationship between the functioning of the MOC reflex and NIHL is necessary.

Contrary to the studies mentioned above, Keppler et al., (2014) noted that the results from contralateral suppression of OAEs could not predict an individual's susceptibility to temporary HL. The strength of the MOC efferent reflex was studied in participants who presented with a temporary emission shift and a temporary behavioural threshold shift in hearing sensitivity after exposure to noise. In the study by Keppler et al., (2014), a comparison between the strength of the MOC efferent reflex and the susceptibility to NIHL could not be determined because the recorded TTS and the measured ES in the individuals who had been exposed to noise were too small to activate the MOC reflex. It was suggested that a larger study group be used and a larger TTS induced, or that the effect on the MOC system be investigated in participants with permanent HL.

2.2. Problem statement

Exposure to excessive noise is one of the most preventable causes of permanent HL worldwide (Trung et al., 2017). As industrialisation increases and life expectancy is prolonged, NIHL will increase the global burden of disability and is, therefore, a concern to public health (Olusanya et al., 2014). During the World Health Organization's (WHO's) informal discussion on the prevention of NIHL in 1997, it was stipulated that the prevention of NIHL should be appropriate, adequate, acceptable, and affordable. Research is, therefore, necessary on pathogenic mechanisms and on procedures to minimise noise, to improve hearing protection, and to contribute to affordable prevention and monitoring of NIHL (Trung et al., 2017; WHO, 1997). Despite the WHO statement more than 20 years ago, NIHL incidences are still on the increase.

If it was possible to predict if an individual is more susceptible to developing a HL even before that individual commences working in a noisy environment, the necessary precautions may be taken to prevent NIHL, especially in a population group more vulnerable to NIHL. The research question of the current study was: What is the role of the MOC efferent reflex strength in the susceptibility to NIHL?

The data collected and analysed in the current research study may afford researchers and other specialists a clearer indication of the possibility of using the strength of the MOC reflex to identify individuals who are more susceptible to developing a NIHL. It is hypothesised that the measurement results of the MOC reflex can be used as part of the medical surveillance examination to identify individuals who are particularly susceptible to developing an NIHL.

3. Chapter 3: Methodology

In this chapter the procedures and planning for the gathering of data are described.

3.1. Aim

The main aim of the study was to determine the relationship between MOC reflex strength, as measured by the contralateral suppression of TEOAEs, and susceptibility to NIHL.

3.2. Hypotheses

For the hypotheses the following null and alternative hypotheses were defined.

H_0: The contralateral suppression of TEOAEs cannot be used to predict the susceptibility of an individual to NIHL.

H_1: The contralateral suppression of TEOAEs can be used to predict the susceptibility of an individual to NIHL.

3.3. Research approach and research design

A research design is a strategic framework that connects research questions and the implementation of the research (Durrheim, 2006). The design used in the current study was a categorical independent design (Leedy & Ormrod, 2013). The independent values used in the study were the results from the contralateral suppression of the TEOAEs and the thresholds obtained from each participant's pure tone audiogram. The results concerning the contralateral suppression of TEOAEs obtained from the two participant groups, namely the participants with normal hearing and participants with a minimal HL, were compared.

As the data was statistically analysed and described, the design could also be considered to be a descriptive comparative research design (Leedy & Ormrod, 2013). Using a descriptive comparative design allowed the researcher to develop a comprehensive and exact description of the characteristics of the functioning and measurements of the MOC reflex (Struwig & Stead, 2001). To apply a descriptive comparative design, a selected quantity of data was collected to answer the research question (Hicks, 2004; Leedy & Ormrod, 2013).

A quantitative research approach was used as different numerical values were collected from each participant (Leedy & Ormrod, 2013). A quantitative approach is an objective evaluation as it analyses specific measurements. It is an approach that guarantees objectivity in the results and the conclusions (Leedy & Ormrod, 2013). The numerical results obtained for each participant were processed to obtain an objective comparison between the two identified groups. The research can be considered to be applied research, as a specific phenomenon in the field of Audiology was investigated.

3.4. Ethical considerations

Permission to conduct the research was obtained from the Research Ethics Committee of the Faculty of Humanities at the University of Pretoria (Appendix A) and the Department of Speech-Language Pathology and Audiology at the University of Pretoria. The following ethical considerations were adhered to in this study.

3.4.1. Autonomy

An informed consent letter was given to each participant before testing could take place (Appendix B). The consent letter contained the information regarding the research study and what was expected of each participant. The same information was given to them verbally in a language they understood before testing commenced. Nursing personnel assisted in providing the spoken information. The participants were ensured that they would not be harmed and that they would be treated with honesty and respect according to their human rights. Each participant could withdraw at any time during the study if they wished to do so without any negative consequences. An informed consent letter was also signed by the mine to authorize permission to use the data collected from each participant in this study (Appendix C).

3.4.2. Confidentiality

Personal information and all results from participants and potential participants were kept confidential at all times. All participants were ensured that only a code number would be used in records, to keep their identities confidential. As guidelines suggest data will be stored in a hard copy and electronically at the Department of Speech-Language Pathology and Audiology at the University of Pretoria for a minimum of 15 years.

3.4.3. Honesty and plagiarism

Honesty was maintained at all times during the study to ensure the validity and reliability of data obtained. Results and data analysis were described in an honest way without suggesting a misleading conclusion (Leedy & Ormrod, 2013) A signed declaration regarding plagiarism can be found after the table of contents. This study was the researchers own original work and all secondary and previous research used in the study was referenced accordingly (SASLHA, 2010).

3.5. Participant selection

In this section the inclusion and exclusion criteria for participant selection are discussed, followed by the material, apparatus and procedure used for participant selection. Sampling methods are explained and the chapter concludes with the discussion and description of the participants.

3.5.1. Sampling methods

Purposive and stratified convenience sampling methods were used (Leedy & Ormrod, 2013). The participants were selected according to their race, gender, occupation, age, degree of HL, and history of exposure to any ototoxic medication. This was to minimise variability between the sample groups and ensure valid and reliable results.

All participants used in the study were identified through the SAP database used at the mine. A list of all employees scheduled for their medical examination at the Occupational Health Centre was given daily to the researcher by the nurses employed by the mine. This list was filtered by using the three selected occupations: Rock Drill Operator (RDO), general production, and team leader production. Employees with other occupations were removed from the list. The majority of employees on this list were African males. Any female or Caucasian employees on the list were automatically removed. The data of the employees who adhered to the criteria as mentioned above was then searched on the SAP database to identify those within the group who were 30 to 45 years of age. Their degree of hearing loss was also viewed on the screening history of the database. Those employees who presented with unilateral HL, bilateral severe HL, or who had an inconsistent screening history were removed from the list. Lastly, their prescribed medication was viewed and employees who had any history of ototoxic medication use were also removed from the list.

The remaining employees identified on the list were recruited from the Occupational Health Centre. They were informed that they had been selected to participate in a research study. More particulars regarding the procedure of the tests and what was expected of them was explained to them by assisting nurses who interpreted the information to them in the language of their choice. The employees who agreed to participate in the study were given an information and consent letter. Those who agreed to participate had to sign the permission letter (Appendix B). The employees selected to participate were also informed that they could withdraw at any point during the testing procedure. Screening procedures were then performed on the prospective participants to determine if they adhered to the remaining inclusion and exclusion criteria to become participants in the study and for their data to be collected as described in the consent letter.

3.5.2. Population

The participants in this study were employees at a Platinum mine in the North West Province in South Africa. Forty-one African males between the ages of 30 and 45 years working either as Rock Drill Operators (RDOs), in general production, or as team leaders were selected. Twenty of the selected participants presented with thresholds considered to be within normal limits, that is between 0 dB and 15 dB (Group A) and the other 21 presented with pure tone threshold classifications of a permanent minimal NIHL at frequencies 3000 Hz, 4000 Hz and 6000 Hz between 16 dB and 40 dB (Group B).

The number of years each participant had been exposed to noise at the mine was also taken into consideration in analysing the statistics, but it was not a criterion for participant selection. It was difficult to obtain an accurate history of noise exposure as most employees in the mining industry have worked at numerous mines in different occupations and have been exposed to different types of noise. The participants included in this study had been exposed to noise for between three and 15 years with a mean of 7.53 years and a standard deviation of 3.01 years.

3.5.3. Inclusion and exclusion criteria

The participants had to comply with all of the following criteria to participate in the research.

3.5.3.1. Occupation

All participants had to work in the same mine in the same environment to minimise the effect of differences in the noise levels and duration of the noise exposure of the participants. The occupations of the participants included RDOs, team leaders, or workers in the general production section. RDOs control, operate, and drive handheld or drilling machinery to drill explosive-charge holes through rock and other hard surfaces to assist in blasting procedures. Rock drilling is one of the mining occupations exposed to the highest noise levels (Edwards et al., 2011). The RDO participants used in the study were exposed to noise levels between 96.0 dBA and 101.6 dBA per shift. Participants working in general production worked in the same area beside the RDOs and were exposed to noise levels between 89.3 dBA and 94.5 dBA per shift. The team leaders also worked in the same area and were exposed to noise levels between 90.4 dBA and 96.6 dBA per shift. These noise levels were recorded by the mine in the respected areas and monitored by the Mine Health and Safety Officer. Long term exposure of 8 hours or more to noise levels of 85 dBA or louder can cause permanent NIHL (WHO, 2020) and therefore these occupations mentioned above increased the likelihood of the participants presenting with a permanent NIHL.

3.5.3.2. Gender and race

Only African male participants were included in the study. There are very few females employed by the mining industry for the selected occupations. OAE responses have also been recorded to be larger in females than in males. These differences observed in the emissions of males and females were present in both neonates and adults (McFadden et al., 2009). With regard to the selection of participants according to race, the majority of workers employed at the mine for the selected occupations are African. Therefore, to ensure a homogeneous participant group and to avoid any outliers in the data analysis, only African male participants were included.

3.5.3.3. Age between 30 to 45 years

Workers had to be between the ages of 30 and 45 years. It is the most likely ages for an NIHL to develop, but for participants to still record present OAEs (Humes et al., 2006). By the age of 30 to 45 years, the participants will most likely have been working in a noisy environment for 10 to 15 years. The largest shift in hearing due to exposure to noise is observed after 10 to 15 years of noise exposure (Humes et al., 2006). Participants older than 45 were most likely to present with a HL of greater than 40 dB with absent ipsilateral or contralateral TEOAEs, due to the possible co-morbidity of presbycusis or the influence of age on the auditory system (Katz et al., 2015).

3.5.3.4. Middle ear functioning

In order to elicit OAEs, it was necessary that the participants had to have normal middle ear functioning. Each participant, therefore, had to present with a type A tympanogram in both ears with compliance values between 0.3 and 1.75 ml; middle ear pressure between 0 and +50 da Pa; and an ear canal volume value of 1 to 1.5 ml (Katz et al., 2015).

3.5.3.5. Acoustic reflexes

As compliance values have been found to be a relatively unreliable measure to confirm the presence of normal middle ear functioning, at least one ipsilateral acoustic reflex threshold had to be present between 80 and 100 dB SPL at either 500 Hz or 1000 Hz in both the ears to confirm that the participants from both groups had normal middle ear functioning (Katz et al., 2015).

3.5.3.6. Audiometric thresholds

Participants from both groups (A and B) had to present with normal low-frequency thresholds. The low-frequency thresholds (average hearing thresholds of 250 Hz, 500 Hz, 1000 Hz and 2000 Hz) had to be between 0 and 15 dB. Participants from group A had average hearing thresholds of equal to or less than 15 dB in the high frequencies (3000 Hz, 4000 Hz and 6000 Hz). NIHL affects the high frequencies first and is most commonly observed at 4000 Hz, although often 3000 Hz and 6000 Hz are also affected (Gelfand, 2009). All participants from Group B had to have a minimal NIHL with an average between 16 dB and 40 dB in the high frequencies (3000 Hz, 4000 Hz and 6000 Hz) collectively (Henderson et al., 2012).

3.5.3.7. Co-morbidities in medical history

Co-morbidities may have affected the results of the research. Therefore, participants with a history of co-morbidities such as head injury or ototoxic medication use that could be an additional cause of HL besides noise exposure were excluded from the study (Bergemalm, 2003; Bisht & Bist, 2011).

3.5.3.8. Contralateral evoked TEOAEs

As contralateral TEOAEs were measured during data gathering, all participants had to have present ipsilateral and contralateral TEOAEs. The TEOAEs were considered present if the amplitude was greater than or equal to 3 dB above the noise level of ≤ 0 dB SPL (signal to noise ratio SNR) (Foreshaw, 2011). The lower the SNR, the less reliable the TEOAE results are and therefore, the larger the margin of error in the results. Present and normal TEOAEs were necessary to compare the ES results to the pure tone results and the results of the other participants. If a participant did not present with present ipsilateral TEOAEs, present contralateral suppression of TEOAEs, or an SNR of ≥ 3 dB, the participant was not included in the study.

3.5.3.9. Noise exposure before testing

To determine the true thresholds for each participant it was necessary that the participants should not have been exposed to noise for 16 hours before testing could take place. This was important to eliminate the possibility of a TTS being present (Humes et al., 2006). Workers at the mine need to clock-in and clock-out with an employee card for every shift they work. The latest check-out time was checked on the system before testing was conducted to ensure that the participants were noise free for 16 hours prior to testing.

3.5.4. Materials and apparatus for selection of participants

The materials and apparatus used for the selection of participants in the study are described below.

3.5.4.1. Informed consent letter to management of the mine

An informed consent letter (Appendix C) was provided to the employer of the participants to obtain permission that employees of the mine may be recruited as participants for the study and that the researcher was permitted to use the data obtained for the purpose of the study in a confidential manner.

3.5.4.2. Informed consent letter to participants

An informed consent letter (Appendix B) was given to each participant before testing could take place to inform them about the study and what was expected from each of them. All information was also given verbally in a language of the participant's choice by nurses employed at the mine.

3.5.4.3. Otoscope

To examine the tympanic membrane and the outer ear of each participant a Welch-Allyn otoscope of 3.5v with reference number 77747 was used.

3.5.4.4. Interacoustics MT10 immittance meter

To determine normal middle ear functioning an Interacoustics MT10 immittance meter with serial number SN601918 calibrated on 20 April 2016 (before data collection commenced) was used (Appendix D). Ipsilateral acoustic reflex measurements were also conducted using the same immittance equipment.

3.5.4.5. Audiometer

A Madsen GN Otometrics Audiometer, calibrated on 04 March 2016 (before data collection commenced) (Appendix E) was used to determine pure-tone thresholds. Supra-aural Telephonics TDH 39P earphones were used, and the soundproof booth of the audiometer was installed in a room with carpet walls for sound insulation.

3.5.5. Procedure for participant selection

Possible candidates for participation were identified from the SAP (Systems, Applications and Products) database used at the mine where all the personal information of employees is stored. On the database, the age, occupation, audiological screening history and previous ototoxic medication history were indicated. All employees at the mine are scheduled for either a six monthly or annual medical screening. On the day of the identified candidates' medical examination, the possible candidates were given information about the study and asked if they would be willing to participate. The testing procedure started after the candidates signed the informed consent letter (Appendix B).

Figure 2 provides a description of the procedure that was followed during the selection of the participants.

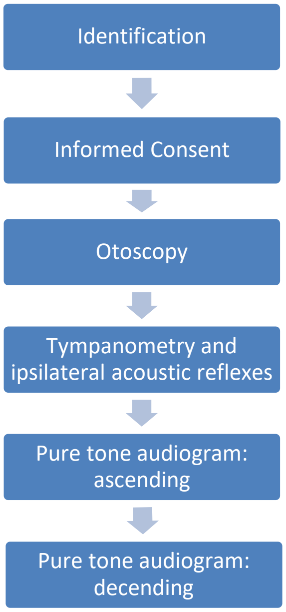

Figure 2: Flow diagram of the procedures used for participant selection

- All participants from Group A and Group B who complied with the selection criteria were identified at the Occupational Health Centre of the mine on the day of their six monthly medical examinations.
- The testing procedure was explained to the participants and they were given the opportunity to withdraw from the study if they wished to do so.
- Once the informed consent (Appendix B) was signed by the participant, testing commenced.
- Otoscopy was done to examine the outer ear and the tympanic membranes of both ears of the participants to ensure that the participants did not present with excessive wax, a perforation, or middle ear pathology that could influence the OAE results (Katz et al., 2015). In the case of excessive wax, the patient was referred to the Occupational Health nurses for the removal of earwax. In the case of a possible perforation or middle ear pathology, a diagnostic audiogram was performed and the participant was referred to the Occupational Health doctors for further management.

- Tympanometry was performed first in the left ear then in the right ear to measure the compliance (values between 0.3 to 1.75 ml), pressure (values between -50 and +50 da Pa) and volume (value of 1 to 1.5 ml) to confirm that no middle ear pathology was present (Katz et al., 2015). At least one acoustic reflex between 80 and 100 dB had to be present either at 500 Hz or 1000 Hz in both ears to confirm normal middle ear functioning (Emanuel, 2009).
- The pure tone testing was performed as per guidelines of the British Society of Audiology (2011). The participant was seated in the soundproof booth and instructed to press the button every time a sound was heard. The earphones were placed on both ears.
- The testing procedure commenced at 1000 Hz then 500 Hz, 250 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz in ascending order, starting at a low decibel value of 0 dB and increasing the sound level by 5 dB increments to determine a threshold at each frequency (Katz et al., 2015). These thresholds were recorded on the audiogram (Appendix F).
- After ten minutes of no noise exposure, a second audiogram was obtained in a descending order, starting at a louder decibel value at the same frequencies as in the previous procedure to determine the reliability of the thresholds.
- The first audiogram was compared to the second audiogram to determine the reliability of the results. If there was a difference of 15 dB or more at more than one frequency, the participant was excluded from the study as the results were deemed unreliable (De Koker, 2004).
- If the participant complied with the selection criteria as described, the participant was included in the study and data gathering could commence.

3.5.6. Considerations with regards to participants' selection

During the process of participant selection, using the specified inclusion and exclusion criteria mentioned in the methodology, several employees at the mine could not be included to participate in the study due to the reasons listed below.

3.5.6.1. Middle ear pathology in the mining industry

A criterion for participant selection in the study was normal middle ear function in both ears. After possible participants were identified on the database, a number of employees could not be included in the study due to the presence of middle ear pathology.

The high prevalence of middle ear pathology in the mining industry could be a result of the pressure changes the employees undergo when being transported underground to the shafts at a rapid speed on a daily basis (Walling, 2000). The pressure changes within the middle ear cavity may result in middle ear pathology or barotrauma when the eustachian tube fails to equalise the pressure in the middle ear (Walling, 2000).

The high prevalence of middle ear pathology in the mining industry could also be related to environmental factors. These factors consist of poverty that results in underprivileged housing, poor hygiene, and insufficient nutrition (World Health Organisation [WHO] & CIBA, 2000). In the mining industry employees may be at risk of occupational and environmental factors that could increase the risk of middle ear pathologies developing (Sebothoma, 2020).

In the mining industry, all employees undergo medical screening once a year. With the screening hearing test, only otoscopy and air conduction tests are performed by an audiometrist using a computer-generated program. Only if the hearing percentage of the employee has shifted with

10% or more the employee is referred to an audiologist for a diagnostic audiogram (SANS 10083, 2013). Many middle ear pathologies go undetected if there is no shift in the pure-tone thresholds. It is recommended that more research should be done regarding middle ear pathology in the mining industry and that immittance testing be included in the medical hearing screening procedure for the early identification of middle ear pathology. Early identification of middle ear pathology may result in a faster recovery process and prevent chronic middle ear pathology from developing.

3.5.6.2. Earwax plugs in the mining industry

Insert earplugs or earmuffs are used in the mining industry to protect the ear from excessive noise exposure. Insert earplugs fit tightly inside the opening of the ear canal. Employees working in high noise areas can wear earplugs for an average of three to eight hours per day. Constant use of the earplugs for long periods of time may cause earwax to build up and block the normal flow of earwax (Katz et al., 2015). After the identification of possible participants for the study, several employees were observed to have earwax plugs in either the left or the right ear. The nurses at the occupational health clinics who screen the employees during their medical examinations should be educated on the importance of identifying and removing earwax plugs, as well as the possible consequences of longstanding earwax plugs.

3.5.6.3. Interpretation of TEOAE-result

One of the criteria for participant selection was that the TEOAE-amplitude of the emissions had to be present with a SNR of ≥ 3 dB above the noise level of ≤ 0 dB SPL at three or more consecutive measured frequencies. The measurement of TEOAEs and the SNR is sensitive to and influenced by the noise in the test environment. Therefore, the less background noise in the test room the more reliable the OAE responses (Hall, 2015). Of the 41 participants tested, six had SNRs of less than 3 dB above the noise level of ≤ 0 dB SPL at more than one measured frequency in the left and the right ear, while five presented with this condition in the left ear only, and three in the right ear only. In total, 24% of the recorded results were therefore not used for the data analysis. The OAE measurements were recorded in a room with carpeted walls and not a soundproof booth due to the size restrictions of the available booth. If the OAE recordings had been done in a soundproof booth the outcome of the SNR could have been improved.

The majority of TEOAE results with a SNR of ≤ 3 dB were observed in the high frequencies at 3000 Hz and 4000 Hz. These are the frequencies first affected by noise. All of the participants had a history of excessive noise exposure which could have negatively affected the SNR results, especially at these frequencies. This was also observed in other studies where OAE measurements in participants exposed to noise were used (Edwards, 2009; Edwards et al., 2010).

3.5.7. Description of participants

Forty-one African males working either as Rock Drill Operators (RDOs), in general production or as team leaders and between the ages of 30 and 45 years were selected. All participants presented with normal middle ear function with no medical co-morbidities.

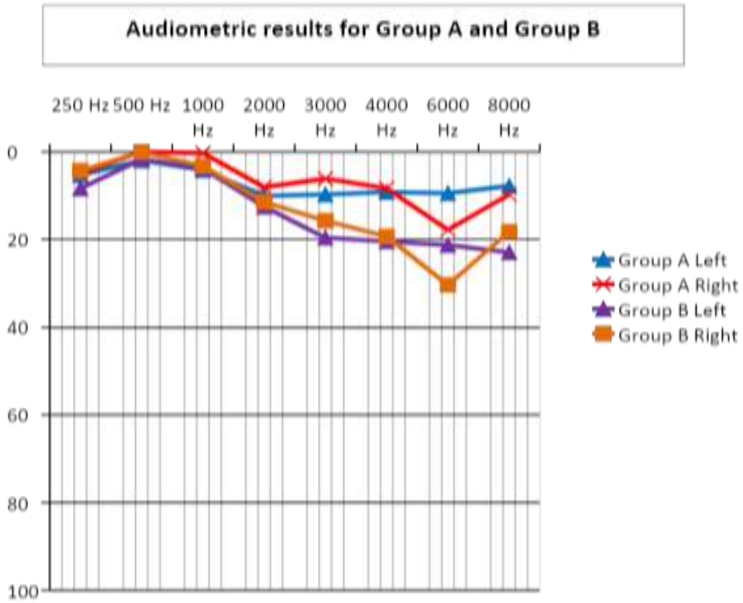

Figure 3: Audiometric results of participants in Groups A and B

The participants were divided into two groups according to their pure tone high-frequency thresholds. All participants in both group A and B had to present with an average low-frequency threshold of equal to or less than 15 dB in both ears. Twenty of the selected participants presented with thresholds considered to be within normal limits, that is, between 0 dB and 15 dB (Group A) and the other 21 presented with pure tone thresholds typical of a permanent minimal NIHL, i.e. between 16 dB and 40 dB at frequencies 3000 Hz, 4000 Hz and 6000 Hz (Group B) (Henderson et al., 2011; Schlauch & Carney, 2012). This is demonstrated in Figure 3.

Furthermore, all participants had hearing thresholds better than 40 dB HL at all measured frequencies in both ears. In a study by Gorga, Neely, and Dorn (1999), it was found that the reliability of OAEs was highest for a HL of less than 40 dB HL. The hearing thresholds better than 40 dB HL ensured that the results from the contralateral suppression of the TEOAEs could be obtained and were reliable.

Six of the 41 prospective participants presented with TEOAE's with a SNR of less than 3 dB at more than one measured frequency in the left and the right ear, five in the left ear only, and three in the right ear only. These results could therefore not be used for the data analysis, and the results of only 35 participants were used. Of the 35 participants, the results of 62 ears could be included in the data analysis.

Table 1: The number of ears used for the data analysis.

	Group A	**Group B**	**Total left and right ears**
Left ears	**18**	**12**	**30**
Right ears	**18**	**14**	**32**
Total ears used for Group A and B	**36**	**26**	**62**

The results of 62 ears (30 left ears and 32 right ears) were used in the final analysis of data. Of the participants who were tested the results of only 36 ears were within the normal pure tone test result values (Group A); 18 in the left ear and 18 in the right ear. Twenty-six tested ears had a minimal HL (Group B); 12 participants with a minimal HL in the left ear and 14 in the right ear. This is indicated in Table 1 above.

3.6. Data collection

The material, apparatus, and procedure for data collection are discussed in this section.

3.6.1. Material and apparatus for data collection

The material and apparatus used for the gathering of data are discussed below.

3.6.1.1. ILO 292 USB

Ipsilateral TEOAEs and contralateral suppression of TEOAEs were measured using the ILO 292 USB II module and the ILO V6 clinical OAE software (Otodynamics Ltd.).

3.6.2. Procedure for data collection

The procedure for data collection is discussed below together with the parameters used for data collection.

3.6.2.1. Pilot study

A pilot study was done before data gathering commenced to ensure the reliability and validity of the equipment and procedures used in the study. The pilot study was conducted with the same procedure and equipment that were used in the research study in the same room at the mine. The five participants who were used for the pilot study were randomly selected. The results of the pilot study are presented in Appendix G.

The pilot study assisted the researcher to estimate the amount of time it would take to complete the collection of data for the study. The duration of the complete testing procedure was on average 30 minutes per participant. It was estimated that it would take six weeks to collect sufficient data for the data analysis.

The pilot study was needed for sufficient planning for data gathering and for feedback to the employers of the participants. No problems or concerns were encountered during the pilot study and therefore, the methods and procedures selected for the study were not adjusted or changed.

The pilot study allowed the researcher to estimate that the duration of the data collection would be feasible and therefore to commence with the study.

3.6.2.2. Parameters for ipsilateral and contralateral suppression of TEOAEs

The parameters that were used for the ipsilateral and contralateral suppression of TEOAEs are summarized in Table 2.

Table 2: Parameters used for eliciting of ipsilateral TEOAEs and contralateral suppression of TEOAEs

Parameters	
Binaural ILO 292 USB Otodynamics Analyser (ILO V6 clinical OAE software)	
Ipsilateral TEOAEs	
Target Stimulus	80 dBpeSPL, non-linear (Lapsley Miller, Marshall & Heller, 2004; Keppler et al., 2014)
Sweeps	260 (Lapsley Miller, Marshall & Heller, 2004; Keppler et al.,, 2014)
Duration	80 µs (Lapsley Miller, Marshall & Heller, 2004; Keppler et al., 2014)
Rate	50 clicks per second (Lapsley Miller, Marshall & Heller, 2004; Keppler et al., 2014)
Contralateral Suppression of TEOAEs	
Masker Level	60 dBpeSPL (Hood et al., 1996; Keppler et al., 2014)
Masker Type	Broadband White Noise (Hood et al., 1996; Keppler et al., 2014)
Stimulus Level	55 dBpeSPL (Hood et al., 1996; Keppler et al., 2014)
Stimulus Type	Linear (Hood et al., 1996; Keppler et al., 2014)
Sweeps	260 (Hood et al., 1996; Keppler et al., 2014)

The parameters used for the measurement of contralateral suppression of the TEOAEs were as follows: clicks were presented at 55 dBpeSPL in the one ear simultaneously with an intermittent contralateral broadband white noise of 10 second intervals presented at 60 dBpeSPL in the opposite ear (Lapsley Miller et al., 2004; Hood et al., 1996; Keppler et al., 2014). The results of the TEOAEs may be enhanced when a lower level stimulus, slightly louder than the stimulus, is used for contralateral noise clicks (Hood et al., 1996; Sliwinska-Kowalska & Kotylo, 2002).

3.6.2.3. Description of procedure for data gathering

The procedure that was used for data collection is depicted in Figure 4. The procedure has been adapted from Keppler et al., (2014).

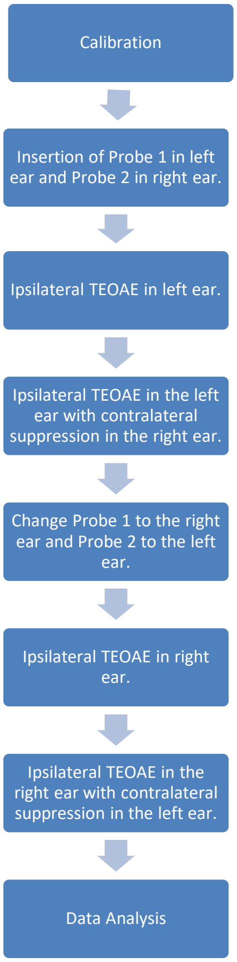

Figure 4: Flow diagram of the procedure for data collection

- The probe tones presented to measure the OAEs were calibrated on a daily basis with the 1 cc calibration cavity provided by the manufacturer before testing commenced.

- The OAE equipment was calibrated for diagnostic testing in a quiet room with carpeted walls for sound insulation.
- The participants were instructed to sit as quietly and as still as possible during testing (Hall, 2015).
- For the OAE measurements, Probe 1 was first inserted and sealed into the left ear, and Probe 2 was subsequently inserted and sealed into the right ear. A probe stability of 99% or higher was accepted as reliable (Hall, 2015).
- Ipsilateral TEOAEs were measured in the left ear with Probe 1 presenting stimuli at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz and calculated in half-octave frequency bands. The low cut filter was activated to assist in a noisy environment. The test automatically stopped after 260 sweeps. TEOAEs were considered present if the amplitude was greater than or equal to 3 dB above ≤ 0 dB SPL (Signal to Noise Ratio [SNR] in at least three consecutive measured frequencies [Foreshaw, 2011]). A SNR of more than 3 dB was used to minimise any results that might be affected by synchronised spontaneous OAEs (SSOAEs). SSOAEs are spontaneous or natural cochlear alternations that can be caused by click stimuli and affect the results of the amplitudes and phases of TEOAEs (Mertes & Goodman, 2016). Therefore, any SNR of less than 3 dB was an indication that abnormal or absent OAEs or SSOAEs might have been present.
- Ipsilateral TEOAEs were measured in the left ear (Probe 1) while contralateral suppression was measured simultaneously in the right ear (Probe 2) using a binaural probe. To reduce noise levels, the low cut filter was activated. The ES was calculated in half-octave frequency bands centred around 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz. The difference in the TEOAE results with suppression and the TEOAE results

without suppression was considered to be the ES. The test automatically stopped after 260 sweeps.

- The noise rejection level for both the ipsilateral TEOAEs and the contralateral suppression of TEOAE-measurements were set at 4 mPa on the software but were adjusted to lower than 4 mPa according to the noise level histogram as more accurate signals may be recorded at lower levels of noise (Hatzopoulos et al., 2003).
- To measure the emissions of the right ear, the probes were changed so that Probe 1 was inserted into the right ear and Probe 2 was inserted into the left ear.
- Ipsilateral TEOAEs and TEOAEs with contralateral suppression were measured using the same procedure as above for the right ear.
- At the end of each day, the measured data was converted to an Excel spreadsheet to be analysed. The procedure for data collection is summarised in Figure 4.

3.7. Recording of data

All data obtained from each participant was recorded on an audiogram sheet displaying all the relevant information (Appendix F). The identities of the participants were kept confidential, as only a number was used to record the data of each participant. The OAE measurements obtained were recorded and saved on the ILO V6 clinical OAE software (Otodynamics Ltd.), as well as on an Excel sheet. The data recorded on the Excel sheet was analysed using the Statistical Package for the Social Sciences (SPSS) program.

3.7.1. Calculation of ES

The ES for each frequency was calculated as the raw difference or the absolute values and a normalised difference or the index of suppression (Stuart & Cobb, 2015). The absolute values were calculated in dB as the TEOAE without contralateral suppression minus TEOAE with contralateral suppression.

Absolute dB values for ES = (TEOAE without suppression) – (TEOAE with suppression)

The index of suppression was calculated as:

$$\text{Index of ES} = \left[\frac{\text{Absolute dB value}}{\text{TEOAE baseline}}\right] \times 100$$

Normal MOC functioning is measured at a 1 dB SPL emission shift caused by the suppression. A value of less than 1 dB SPL was considered abnormal (Collet, 1993; Prasher et al., 1994). The higher the sum of the difference of the TEOAE-results for the ES, the stronger the MOC reflex was considered to be for each participant. Therefore, the strength of the MOC reflex was considered stronger the higher the value of the ES.

The level of significance that was used for this study was equal to 0.05. Therefore, if the p-value was < 0.05, it was considered to be a statistically significant difference at the 5% level of significance (Williams et al., 2009) and the alternative hypothesis (H_1) would be confirmed.

3.7.2. Data analysis

The data was analysed using the SPSS program version 25 (IBM Inc.). Non-parametric tests were used with the Mann-Whitney U test, where the two independent groups were compared (Dodge, 2008). A statistician was consulted for the data analysis of the study. The ES results of the group of normal-hearing participants (Group A) were compared with the ES results of the group of participants with a minimal HL (Group B). The results of the two participant groups were compared with regard to the following four parameters: (1) according to the ES for the left and the right ears separately at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz, (2) according to the ES for the left and the right ears combined at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz, (3) according to different age categories of 30 to 35 years, 36 to 40 years and 41 to 45 years, and lastly, (4) according to years of noise exposure comparing only participants with a history of occupational noise exposure of 10 years or more.

To test for normality, SPSS uses the Kolmogorov-Smirnov and Shapiro-Wilk test statistics along with the corresponding p-values. These two tests are the same in that they both test for normality. However, the Shapiro-Wilk test is known to have more power in detecting differences from normality (Field, 2017). Accordingly, the results of the Shapiro-Wilk test were recorded. If the p-value of the ES results were greater than 0.05, the data was considered to be normally distributed and parametric tests were used. On the other hand, if the p-value was less than 0.05, the data differed from normality, and nonparametric tests were used.

Table 3: Statistical tests of normality

Tests of normality						
	Kolmogorov-Smirnov[a] (Dodge, 2008).			Shapiro-Wilk (Dodge, 2008).		
	Statistic	Degrees of freedom	Significance probability	Statistic	Degrees of freedom	Significance probability
Signal 1kHz	0.239	62	**0.000**	0.534	62	**0.000**
Signal 1.5kHz	0.170	62	**0.000**	0.914	62	**0.000**
Signal 2kHz	0.123	62	**0.022**	0.947	62	**0.010**
Signal 3kHz	0.149	62	**0.001**	0.907	62	**0.000**
Signal 4kHz	0.150	62	**0.001**	0.811	62	**0.000**
a. Lilliefors Significance Correction						

Each frequency (1000 Hz, 2000 Hz, 3000 Hz and 4000 Hz) was tested separately. Since all of the *p*-values at each frequency in Table 3 were less than 0.05, it was deduced that the data used in the study was not normally distributed and, consequently, nonparametric tests were used. Nonparametric tests do not require assumptions about the form of the distribution of the measurements (Dodge, 2008).

The Mann-Whitney U test is a nonparametric test used for testing differences between two independent groups (Dodge, 2008). The Mann-Whitney U test works by assembling the calculations of the two groups that were compared in a ranked list from the lowest calculation to the highest calculation. To obtain a p-value the test compared the sum of the ranks of the two groups (Dodge, 2008).

When interpreting the results, the focus was on the exact *p*-value, which is used when working with smaller values of *n*, where *n* denotes the sample size. The reason is that asymptotic results obtained from small datasets can be misleading. Exact tests were used to obtain an accurate significance level without relying on assumptions that might not be met by the data. The exact significance is therefore always reliable, regardless of the size, distribution, sparseness, or balance of the data. If the exact significance could not be calculated, the asymptotic results were used (Dodge, 2008).

3.8. Reliability, validity and trustworthiness

Reliability refers to the consistency with which the instrument used for the measurement of a specific area yields consistent test-retest results (Leedy & Ormrod, 2013). All of the procedures used for this study were performed in the same consistent manner by the same tester for each participant, thereby increasing the reliability.

The reliability of the results for the contralateral suppression of the TEOAEs has previously been studied by Mishra and Lutman (2013) and again by Stuart and Cobb (2015). Both studies investigated test-retest measurements of the MOC reflex with contralateral suppression of TEOAEs. Both studies found good consistency and confirmed that the contralateral suppression of TEOAEs is a sufficient and a reliable measurement to monitor the MOC reflex.

Conversely, Mertes and Goodman (2016) found that a varied range of within and across subject inconsistency of MOC shifts were present in their study group. They concluded that the use of contralateral TEOAEs to measure the MOC might be too variable for clinical use. However, the study only consisted of 24 participants, and they recommended using a larger sample group to confirm their findings.

In order to determine the validity of a test, one needs to determine the degree to which a test measures what it claims to measure (Leedy & Ormrod, 2013). A pilot study was conducted to ensure the validity of the equipment and that procedures were accurate. All the equipment used was calibrated.

The results were reported in an honest manner to ensure trustworthiness. Ethical clearance was obtained from the Research Ethics Committee, Faculty of Humanities, University of Pretoria (Appendix A) and all potential sources used were referenced accordingly. In this study it was important to conduct all procedures ethically, as human participants were used (SASLHA, 2010).

4. Chapter 4: Research results

4.1. Introduction to results

In two months of data collection at the Occupational Health Centre of a mine in South Africa, 62 ears were identified from 35 participants who complied with the inclusion and exclusion criteria of the study. Thirty-six ears presented with normal hearing and were used for data analysis for Group A, 18 left ears and 18 right ears. Twenty-six of the ears tested had a minimal HL (Group B) 12 left ears and 14 right ears.

The ES of each ear of the participants was manually calculated at each tested frequency. For the data analysis a significance level of 0.05 (5%) was used to indicate if a significant correlation was present in the ES data. To calculate the ES the measured value obtained for the TEOAE with suppression was deducted from the measured value obtained for the TEOAE without suppression. The ES results and the TEOAE results with suppression and without suppression for each participant are presented in Appendix H.

The calculated ES results for each participant at each tested frequency in the left and right ears for Group A and Group B separately are recorded in Tables 4, 5, 6 and 7. Each table is visually displayed in Figures 5, 6, 7 and 8.

Table 4: Results of the ES in dB in the left ears of Group A calculated at each tested frequency

Participant number	Age	Signal-1kHz	Signal-1.5kHz	Signal-2kHz	Signal-3kHz	Signal-4kHz
1	**30**	0,5	0,1	0,2	0,2	0,1
3	**44**	0,3	-0,1	-0,1	0,3	0
4	**33**	-0,1	0,2	-0,2	0,6	0,5
9	**34**	0,1	0,5	0,4	-0,3	0,2
10	**31**	1,8	0,2	1	1,5	-0,4
13	**32**	0,2	0,2	0,2	0,3	-0,1
20	**44**	0,5	0,1	-0,1	0,2	-0,2
21	**33**	0,7	0,6	0,5	0,8	0,4
22	**36**	0,8	-0,7	0,6	0	0,2
24	**33**	0	0,2	0,4	-0,1	-0,3
25	**36**	-0,4	0,1	0,4	0,1	-0,7
26	**38**	-0,6	0	0,1	0,7	0,3
27	**33**	0,4	1	0,2	0,1	0,6
31	**30**	0,6	0,4	0,5	0,2	-0,2
33	**34**	-0,5	0,3	-0,2	-0,1	-0,2
37	**33**	-0,2	0,1	0,3	-0,1	-0,2
39	**34**	0,7	0,2	0	-0,2	-0,3
40	**32**	1,6	0	0,2	0,1	0,1

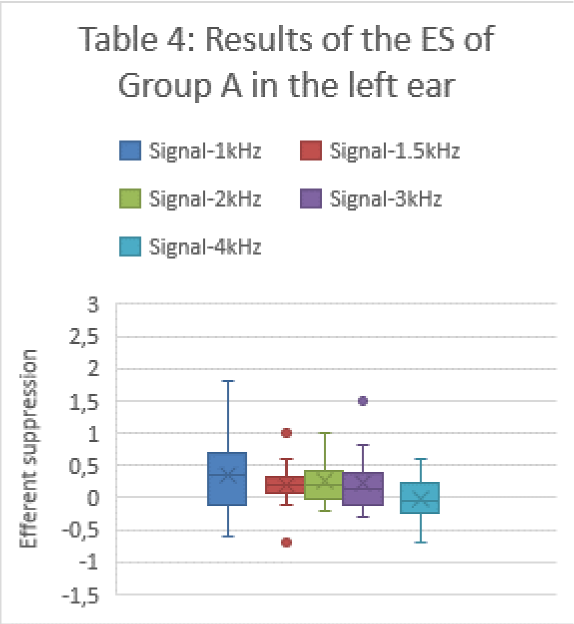

Figure 5: Representation of Table 4. Results of the ES in the left ears of Group A

Table 4 and Figure 5 show the ES calculated at each tested frequency in the left ear for the 18 participants from Group A. Three outlier values were present. Participant 22 presented with a -0.7 dB ES at 1500 Hz, participant 27 presented with a 1 dB ES at 1500 Hz and participant 10 presented with a 1.5 dB ES at 3000 Hz. In Figure 5 it can be noted that the ES at 1000 Hz was slightly higher than at the other frequencies and gradually decreased after every tested frequency, so that 4000 Hz recorded the lowest ES values. Table 5 and Figure 6 show the ES calculated at each tested frequency in the right ear for the 18 participants from Group A.

Table 5: Results of the ES in dB in the right ears of Group A calculated at each tested frequency

Participant number	Age	Signal-1kHz	Signal-1.5kHz	Signal-2kHz	Signal-3kHz	Signal-4kHz
1	**30**	0,4	0,3	0,1	0,2	-0,1
4	**33**	-6,4	-0,9	0,1	0,2	-0,6
10	**31**	0,7	0,4	0,6	0,6	-0,1
13	**32**	0,7	0	0,4	0,2	0,3
14	**34**	-0,3	0,4	0,2	0,1	-0,5
21	**33**	0,2	0,1	0,2	-0,2	-0,1
22	**36**	0,7	0,7	0,1	0	0,3
24	**33**	0,4	0,3	0,2	0,2	-0,2
25	**36**	0,3	0,2	0,1	0,2	0,1
26	**38**	0	0,5	0,3	0,4	-0,1
27	**33**	0,4	0,9	1,2	0,2	-0,9
31	**30**	0,2	0,2	0,6	0,4	1
34	**39**	0,8	0,4	0,1	0	2,5
36	**34**	0,2	0,1	0,5	0,1	-0,1
37	**33**	0,2	0	0	0,3	-0,2
39	**34**	0,3	0,1	-0,3	-0,1	0,4
40	**32**	1,7	-0,5	0,6	0,1	-0,1
41	**32**	0,3	0,1	0,7	0	-0,1

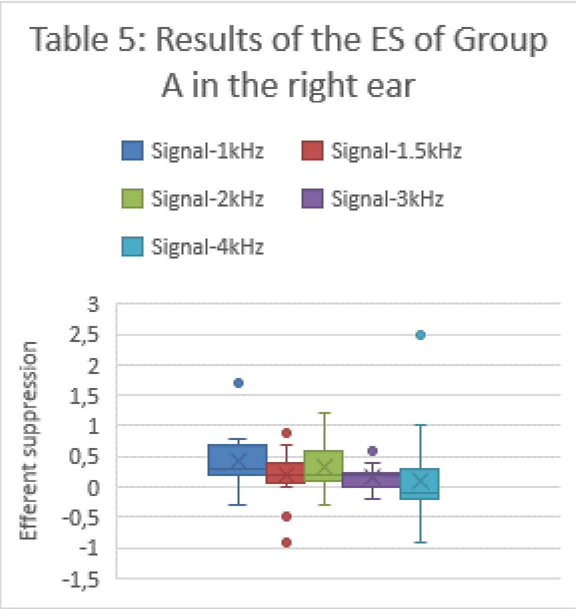

Figure 6: Representation of Table 5. Results of the ES in the right ears of Group A

In Table 5 two outlier values were present at 1000 Hz. Participant 4 presented with a -6.4 dB ES and participant 40 presented with a 1.7 dB ES. The result of participant 4 at 1000 Hz was not included in Figure 6 to display the results in a more legible format. Three outlier values were present at 1500 Hz. Participant 4 presented with a -0.9 dB ES, participant 27 presented with a 0.9 dB ES and participant 40 presented with a -0.5 dB ES. One outlier value was present at 3000 Hz for participant 10 with a 0.6 dB ES. One outlier value was present at 4000 Hz for participant 34 with a 2.5 dB ES. The gradual decreasing slope in the ES values was evident again in Figure 6. The ES was slightly higher at 1000 Hz than at the other frequencies and gradually decreased again at the higher frequencies. The lowest ES values were recorded at 4000 Hz.

Table 6 and Figure 7 show the ES in dB calculated at each tested frequency for the left ears of the 12 participants from Group B.

Table 6: Results of the ES in dB in the left ears of Group B calculated at each tested frequency

Participant number	Age	Signal-1kHz	Signal-1.5kHz	Signal-2kHz	Signal-3kHz	Signal-4kHz
2	**30**	0,2	0,1	-0,1	0,3	0,7
5	**39**	0	0,5	-0,2	-0,1	0,1
6	**31**	0,3	0,3	0,3	0	0,6
14	**34**	0,2	-0,1	0,3	-0,4	0,1
15	**43**	0,4	0,2	0,2	0,3	-0,1
18	**41**	0,5	0,1	0,2	0	-0,3
23	**45**	0,3	0,5	0	0,2	0,4
28	**35**	0,3	0,3	0	0,6	0,3
30	**41**	-0,2	0,2	0,3	0,1	0,5
32	**44**	0,3	0,4	0,2	0,3	3
34	**39**	0,4	0,1	0,3	0,3	-0,5
36	**34**	-0,5	-0,1	0,5	0	0

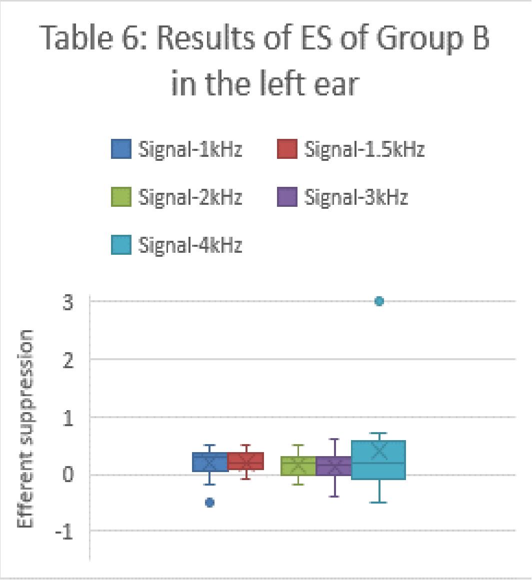

Figure 7: Representation of Table 6. Results of the ES in the left ear of Group B

In Figure 7 it is evident that one outlier value was present at 4000 Hz with a 3 dB ES for participant number 32. The gradual decreasing slope was not as evident in Figure 7 in Group B in the left ear compared to the gradual decreasing slope in Figures 5 and 6. The highest ES values were recorded at 4000 Hz. The ES results were also calculated for Group B in the right ears in Table 7 and visually displayed in Figure 8.

Table 7: Results of the ES in dB in the right ears of Group B calculated at each tested frequency

Participant number	Age	Signal-1kHz	Signal-1.5kHz	Signal-2kHz	Signal-3kHz	Signal-4kHz
2	**30**	0,2	0	0,3	0,6	-0,2
3	**44**	0,1	0,1	0	0,2	-0,6
5	**39**	0,8	0,4	0,5	0,5	0
6	**31**	0,3	0,4	0	0,8	0,7
7	**36**	-0,3	0,6	1	-1,3	0,2
9	**34**	0,2	0	0	0,2	0,4
15	**43**	1,4	1	-0,1	0,6	-0,5
16	**44**	0,4	0	0,1	-0,8	-0,3
17	**42**	1,1	0,4	0,4	0,4	1,6
18	**41**	0,1	0,1	0,4	0	0,6
19	**42**	0,8	0	0,1	-0,3	-0,8
23	**45**	0,3	0	0,2	0,3	0,2
28	**35**	0,4	0	0,3	0	-0,8
30	**41**	0,2	0,3	-0,2	0	-0,2

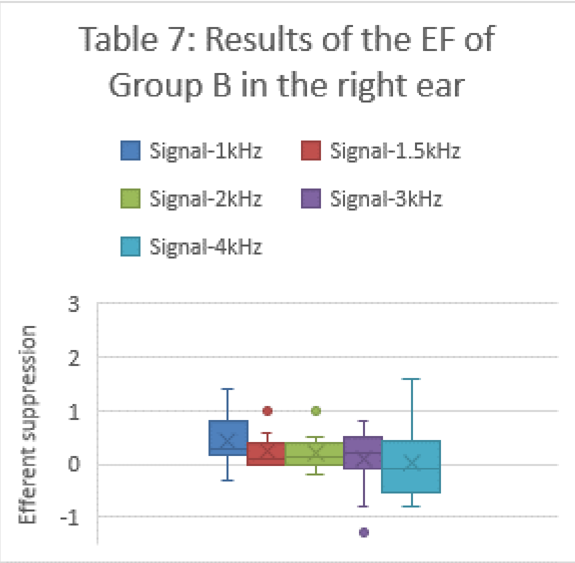

Figure 8: Representation of Table 7. Results of the ES in the right ears of Group B

Table 7 and Figure 8 show the ES in dB in the right ears of Group B calculated at each tested frequency for the 14 participants. The gradual decreasing slope of the ES values at each frequency is evident again in Figure 8. The ES at 1000 Hz is slightly higher than at the other frequencies and gradually decreased towards the higher frequencies with the lowest ES values recorded at 4000 Hz.

All the ES results in Tables 4, 5, 6 and 7 were used and compared to calculate the p-values in the subdivisions below in order to answer the research question.

4.2. Results of the ES in the left and right ears combined of the two participant groups.

The total number of ears from both groups of participants was 62. The ES of the 36 normal-hearing ears was compared to the ES of the 26 ears with a minimal HL at each tested frequency. The results for the ES at each frequency using the left and the right ears combined are summarised in Table 8.

Table 8: Results of the ES in dB of the ears of the two participant groups combined

	Hearing category	N	Mean Rank	Sum of Ranks	Mann-Whitney U (Dodge, 2008)	Exact Sig. (2-tailed): P-value
Signal 1kHz	A	36	32.22	1160.00	442.000	0.714
	B	26	30.50	793.00		
	Total	62				
Signal 1.5kHz	A	36	31.79	1144.50	457.500	0.883
	B	26	31.10	808.50		
	Total	62				
Signal 2kHz	A	36	33.63	1210.50	391.500	0.276
	B	26	28.56	742.50		
	Total	62				
Signal 3kHz	A	36	31.53	1135.00	467.000	0.991
	B	26	31.46	818.00		
	Total	62				
Signal 4kHz	A	36	29.74	1070.50	404.500	0.368
	B	26	33.94	882.50		
	Total	62				

N = Number of ears
Mean rank = average ranked from lowest to highest
Sum of rank = Total ranks added together

The lowest p-value recorded was 0.276 at 2000 Hz. Since none of the p-values calculated were smaller than 0.05, no statistically significant differences between the two participant groups for the left and right ears for all the frequencies tested were obtained.

4.3. Results of the ES of the two participant groups in the left and right ears separately

The ES for the normal hearing participants were compared to the ES of the participants with a minimal HL for the left and right ears separately. A comparison of the ES between Group A and Group B when only using the left ears are displayed in Table 9.

Table 9: Comparison of ES results in dB between the left ears of the two participant groups

	Hearing category	**N**	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney U** (Dodge, 2008).	**Exact. Sig. (2-tailed): P-value**
Signal 1kHz	A	18	16.53	297.50	89.500	0.444
	B	12	13.96	167.50		
	Total	30				
Signal 1.5kHz	A	18	15.14	272.50	101.500	0.791
	B	12	16.04	192.50		
	Total	30				
Signal 2kHz	A	18	16.28	293.00	94.000	0.568
	B	12	14.33	172.00		
	Total	30				
Signal 3kHz	A	18	15.69	282.50	104.500	0.892
	B	12	15.21	182.50		
	Total	30				
Signal 4kHz	A	18	13.50	243.00	72.000	0.130
	B	12	18.50	222.00		
	Total	30				
					Average ES for the left ears	0.765

N = Number of ears
Mean rank = average ranked from lowest to highest
Sum of rank = Total ranks added together

Eighteen ears were used from Group A and 12 ears were used from Group B, totalling 30 left ears of the participants. The emission shift at each frequency was calculated separately at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz. In Table 9 the p-values obtained for the differences in the ES of the left ears of the participants of the two groups at each of the frequencies tested are presented. The lowest p-value recorded was 0.130 at 4000 Hz. Since none of the p-values obtained was smaller than 0.05, no statistically significant differences in ES were measured between the participants of the two groups for the left ears for all the frequencies tested. The results obtained when the ES in the right ears of the two groups of participants were compared are summarised in Table 10.

Table 10: Comparison of ES results in dB between the right ears of both participant groups

	Hearing category	N	Mean Rank	Sum of Ranks	Mann-Whitney U (Dodge, 2008).	Exact. Sig. (2-tailed): P-value
Signal 1kHz	A	18	16.31	293.50	122.500	0.902
	B	14	16.75	234.50		
	Total	32				
Signal 1.5kHz	A	18	17.08	307.50	115.500	0.696
	B	14	15.75	220.50		
	Total	32				
Signal 2kHz	A	18	18.08	325.50	97.500	0.283
	B	14	14.46	202.50		
	Total	32				
Signal 3kHz	A	18	16.11	290.00	119.000	0.798
	B	14	17.00	238.00		
	Total	32				
Signal 4kH	A	18	16.86	303.50	119.500	0.814
	B	14	16.04	224.50		
	Total	32				
					Average ES for the right ears	0.699

N = Number of ears
Mean rank = average ranked from lowest to highest
Sum of rank = Total ranks added together

The number of right ears of participant group A was 18, while 14 ears were used from group B, totalling 32 right ears used in the calculations. The emission shift was calculated separately at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz and then compared between the right ears of the two participant groups. In Table 10 the p-values obtained for the ES differences between the right ears of the two participant groups at each of the frequencies tested, are summarised. The lowest p-value recorded was 0.283 at 2000 Hz. Since none of the p-values obtained was smaller than 0.05, no statistically significant difference in the emission shift for the right ears between the two participant groups was obtained.

When the average ES is calculated using all frequencies at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz, a 0.765 ES is calculated in the left ears in Table 9 and a 0.699 ES is calculated in the right ears in Table 10. The participants in this study therefore presented with a slightly stronger ES in the right ears than the left ears using the average of all frequencies.

Figure 9 displays the ES results of Tables 8, 9 and 10 combined. As indicated in Tables 8, 9 and 10, no significant differences in emission shift were calculated when comparing the left or the right ears of the two participant groups.

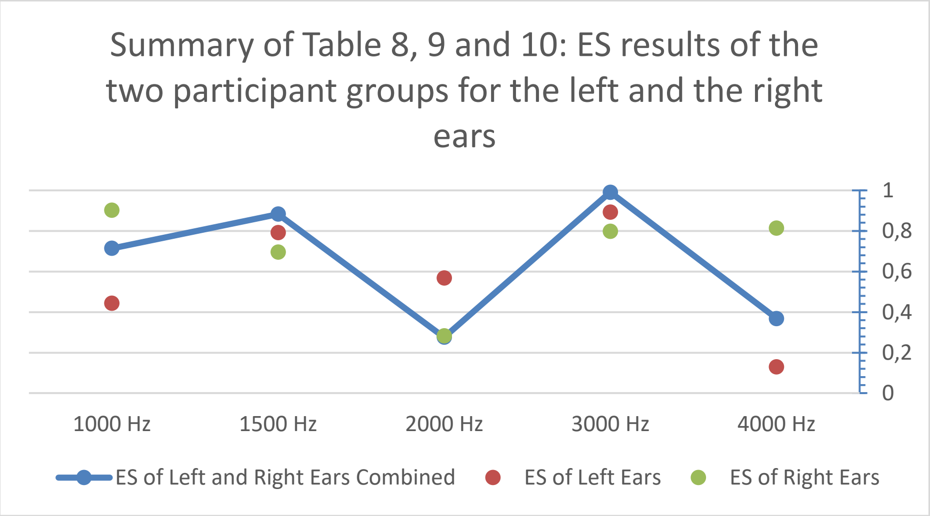

Figure 9: Summary of Tables 8, 9 and 10 - ES results in dB of the two participant groups for the left and the right ears

All age categories were used to compare the results in ES of the left and the right ears of the two participant groups, as indicated in Tables 8, 9 and 10. It is evident in Figure 9 that the largest difference between the ES of the left and the right ears is at 4000 Hz with an ES recorded at 0.814 in the right ears and 0.130 in the left ears. Although the average ES using all frequencies indicates that the ES is slightly stronger in the right ears in Tables 9 and 10, the ES at 4000 Hz alone indicates that the left ears are stronger than the right ears. The results obtained for the different age categories are described under 4.4.

4.4. Comparison of ES results in dB between participant groups for different age categories

The participants were divided into three age categories. The minimum age of the participants was 30 years and the maximum age 45 years, with a mean age of 35.94 years (standard deviation = 4.65). Data from thirty-six ears were used of participants in the 30 to 35-year age group, 27 ears of participants from Group A and 9 ears from Group B. Eleven ears were from participants between 36 and 40 years of age, 7 ears from Group A and 4 ears from Group B. Fifteen ears were from participants between 41 and 45 years of age, 2 ears from Group A and 13 ears from Group B. The results are presented in Table 11.

Table 11: Comparison of ES results in dB between participant groups A and B for different age categories

Age categories	Frequency	Hearing category	N	Mean Rank	Sum of Ranks	Exact Sig. [2-tailed]: P-value
30-35 years	**Signal 1kHz**	A	27	19.50	526.50	0.329
		B	9	15.50	139.50	
		Total	36			
	Signal 1.5kHz	A	27	20.00	540.00	0.139
		B	9	14.00	126.00	
		Total	36			
	Signal 2kHz	A	27	19.57	528.50	0.296
		B	9	15.28	137.50	
		Total	36			
	Signal 3kHz	A	27	18.06	487.50	0.670
		B	9	19.83	178.50	
		Total	36			
	Signal 4kHz	A	27	16.76	452.50	0.085
		B	9	23.72	213.50	
		Total	36			
36-40 years	**Signal 1kHz**	A	7	5.93	41.50	0.976
		B	4	6.13	24.50	
		Total	11			
	Signal 1.5kHz	A	7	5.36	37.50	0.445
		B	4	7.13	28.50	
		Total	11			
	Signal 2kHz	A	7	5.50	38.50	0.533
		B	4	6.88	27.50	
		Total	11			
	Signal 3kHz	A	7	6.43	45.00	0.648
		B	4	5.25	21.00	
		Total	11			
	Signal 4kHz	A	7	6.71	47.00	0.388
		B	4	4.75	19.00	
		Total	11			
41-45 years	**Signal 1kHz**	A	2	9.00	18.00	0.819
		B	13	7.85	102.00	
		Total	15			
	Signal 1.5kHz	A	2	3.75	7.50	0.190
		B	13	8.65	112.50	
		Total	15			
	Signal 2kHz	A	2	3.00	6.00	0.086
		B	13	8.77	114.00	
		Total	15			
	Signal 3kHz	A	2	9.75	19.50	0.657
		B	13	7.73	100.50	
		Total	15			
	Signal 4kH	A	2	7.75	15.50	0.971
		B	13	8.04	104.50	
		Total	15			

N = Number of ears
Mean rank = average ranked from lowest to highest
Sum of rank = Total ranks added together

No significant differences in emission shifts between the two participant groups were obtained for any of the age categories at any frequency, since none of the p-values were smaller than 0.05. The lowest p-value was recorded at 4000 Hz for the age category 30 to 35 with a p-value of 0.085. However, if a calculation with a 10% level of significance is used, a significant difference in ES between groups A and B for the age category 30 to 35 at 4000 Hz was obtained. With such a calculation a p-value of 0,086 at 2000 Hz for the age category 41 to 45 is calculated, which also indicates a significant ES between the two participant groups. The ES results of the three age categories in Table 11 is summarised in Figure 10.

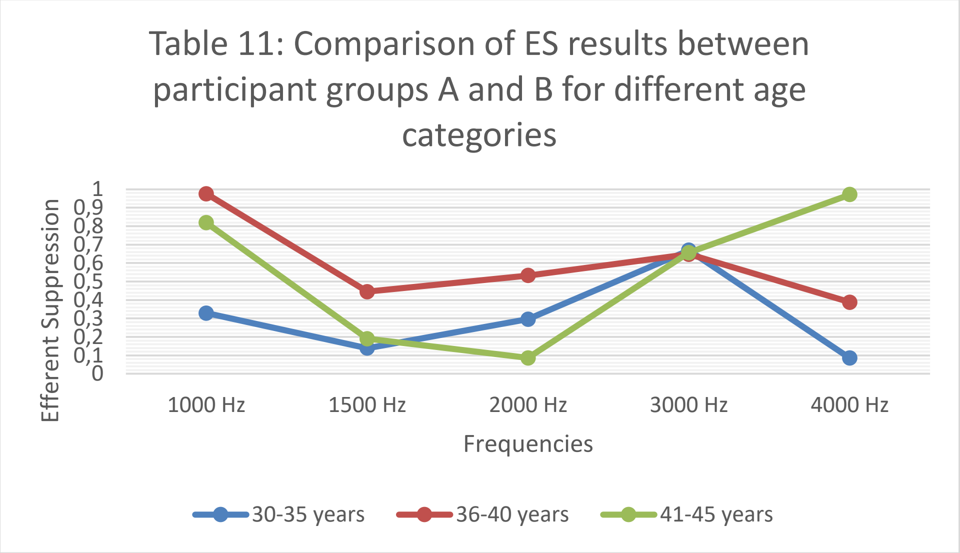

Figure 10: Summary of table 11 – Comparison of ES results in dB between participant groups A and B for different age categories

In Figure 10 all three age categories present with the same 'S' shaped line graph with higher ES results at 1000 Hz, lower ES results at 1500 Hz and 2000 Hz, higher ES results at 3000 Hz, and again lower ES results at 4000 Hz, with the age category of 41 to 45 years being an exception at 4000 Hz.

Each participant had a different noise exposure history, regardless of age. Some 30 year olds had a noise exposure history of 10 years or more and some 45 year olds had a noise exposure history of less than 10 years. The ES results for only the participants with 10 years of noise exposure or more is discussed in the next section.

4.5. Results according to years of noise exposure

The number of years each participant has been exposed to noise in the working environment was not indicated as a criterion for inclusion of participants in the study. The majority of workers in the South African mining industry do not work at the same mine or mining company throughout their careers. There is a system in use, called the Teba history, to keep a record of each employee's occupational history in the mining industry. However, these documents are not entirely accurate and do not always include the occupation or noise exposure levels of the employee during different periods. For the study it was, therefore, decided not to use the Teba history but to only use the more accurate information available at the mine where data gathering was done.

The participants used in the study have been exposed to noise in the mining industry for a minimum of three years to a maximum of 19 years at the mine where data gathering was done, with a mean of 7.65 years and a standard deviation of 3.27. It is highly probable that the majority of these participants were also exposed to occupational noise in their working careers prior to commencing working at the current mine. A comparison was made using only participants with a history of noise exposure of 10 years or more to determine if the participants who present with normal hearing thresholds after 10 years or more of noise exposure have a stronger MOC than the participants who presented with a minimal HL after the same duration of noise exposure. Humes et al., (2006) suggested that noise exposure of 10 to 15 years caused the largest permanent threshold shift.

Table 12: Comparison of the ES in dB of the participants of the two groups exposed to noise for 10 years or more

	Hearing category	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Exact. Sig. (2-tailed): P-value
Signal 1kHz	A	9	9.50	85.50	40.500	1.000
	B	9	9.50	85.50		
	Total	18				
Signal 1.5kHz	A	9	9.56	86.00	40.000	0.995
	B	9	9.44	85.00		
	Total	18				
Signal 2kHz	A	9	9.11	82.00	37.000	0.778
	B	9	9.89	89.00		
	Total	18				
Signal 3kHz	A	9	10.06	90.50	35.500	0.682
	B	9	8.94	80.50		
	Total	18				
Signal 4kHz	A	9	8.56	77.00	32.000	0.474
	B	9	10.44	94.00		
	Total	18				

N = Number of ears
Mean rank = average ranked from lowest to highest
Sum of rank = Total ranks added together

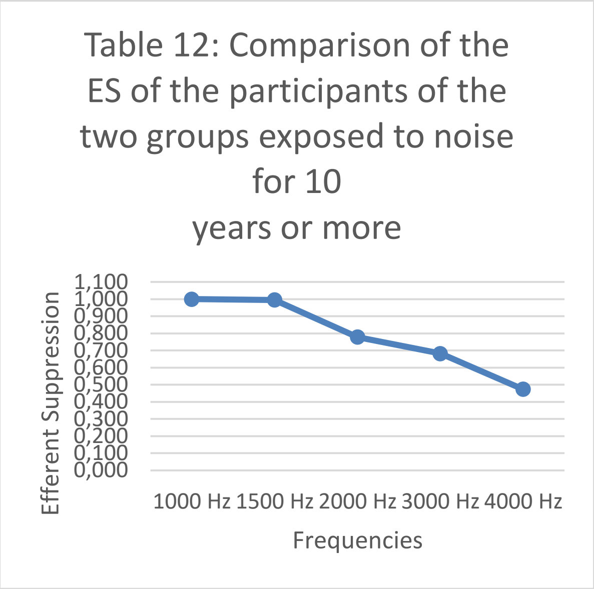

Figure 11: Summary of Table 12 – Comparison of the ES of the participants of the two groups exposed to noise for 10 years of more

Nine ears from both participant groups (N=18) were included in the sample of participants who had been exposed to noise for 10 years or more. The p-values of the ES calculated between the two participant groups at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz are presented in Table 12 and Figure 11. The data collected from the 18 ears of participants exposed to noise for 10 years or more were analysed separately at each frequency. The lowest p-value was recorded at 0.474 at 4000 Hz. However, no statistically significant differences in ES were found between the two participant groups. The gradual decreasing slope in the ES values is evident again in Figure 11. The ES at 1000 Hz is slightly higher than at the other frequencies and gradually decreases at 2000 Hz and 3000 Hz, while the lowest ES values were recorded at 4000 Hz.

4.6. ES results according to the minimum, maximum, mean and standard deviations of groups A and B

The minimum, maximum, mean and standard deviation p-values of the ES results were compared between the participant groups for the left and the right ears combined. In Group A, 18 left ears of participants were included in the calculations and 18 right ears. In Group B, the data of 12 left ears of the participants and 14 right ears were included in the analysis.

Table 13: Descriptive ES results in dB between participants of Group A and Group B

Group	Left or Right ears	Frequency	N	Minimum	Maximum	Mean	Std. deviation
Group A	Left	Signal-1kHz	18	-0,60	1,80	0,356	0,647
		Signal-1.5kHz		-0,70	1,00	0,189	0,339
		Signal-2kHz		-0,20	1,00	0,244	0,309
		Signal-3kHz		-0,30	1,50	0,239	0,434
		Signal-4kHz		-0,70	0,60	-0,011	0,339
		Standard deviation for ES at all frequencies in the left ear					**0,414**
	Right	Signal-1kHz	18	-6,40	1,70	0,044	1,661
		Signal-1.5kHz		-0,90	0,90	0,183	0,405
		Signal-2kHz		-0,30	1,20	0,317	0,340
		Signal-3kHz		-0,20	0,60	0,161	0,191
		Signal-4kHz		-0,90	2,50	0,083	0,729
		Standard deviation for ES at all frequencies in the right ear					**0,665**
Group B	Left	Signal-1kHz	12	-0,50	0,50	0,183	0,286
		Signal-1.5kHz		-0,10	0,50	0,208	0,202
		Signal-2kHz		-0,20	0,50	0,167	0,202
		Signal-3kHz		-0,40	0,60	0,133	0,257
		Signal-4kHz		-0,50	3,00	0,400	0,894
		Standard deviation for ES at all frequencies in the left ear					**0,368**
	Right	Signal-1kHz	14	-0,30	1,40	0,429	0,448
		Signal-1.5kHz		0,00	1,00	0,236	0,300
		Signal-2kHz		-0,20	1,00	0,214	0,306
		Signal-3kHz		-1,30	0,80	0,086	0,572
		Signal-4kHz		-0,80	1,60	0,021	0,662
		Standard deviation for ES at all frequencies in the right ear					**0,458**

N = Number of ears

The standard deviation for all ES results at all frequencies in the left ear was recorded at 0.414 dB for normal hearing participants and a lower value of 0.368 dB for participants with a minimal HL. The standard deviation for the ES at all frequencies in the right ears of the participants was recorded at 0.665 dB for normal hearing participants and a lower value of 0.458 dB for participants with a minimal HL. The higher the ES value, the stronger the MOC reflex and the lower the ES value, the weaker the MOC reflex. Higher ES values were evident for both the left and the right ears independently at 1000 Hz, 1500 Hz and 2000 Hz in Group A (the normal hearing group) compared to the standard deviation obtained for Group B (the minimal hearing loss group). The standard deviation calculated in the ES of participants from Group A at 1000 Hz was 0.647 for the left ears and 1.661 for the right ears, compared to the lower ES values of the participants from Group B of 0.286 for the left ears and 0.448 for the right ears. When comparing the values at 1500 Hz, the ES of participants from Group A was 0.339 for the left ears and 0.405 for the right ears while the results recorded for Group B indicated a lower standard deviation of 0.202 for the left ears and 0.300 for the right ears. This is again evident at 2000 Hz where the standard deviation of the ES calculated for the participants from Group A was 0.309 for the left ears and 0.340 for the right ears, while the standard deviation in ES obtained for the participants from Group B was at lower values of 0.202 for the left ears and 0.306 for the right ears. Higher standard deviation values were also calculated at 3000 Hz in the left ears of participants from Group A (0.434) compared to 0.257 for Group B and at 4000 Hz in the right ears of participants (0.729) from Group A and 0.662 for the participants from Group B. The minimum, maximum, mean and standard deviation ES results are indicated in Table 13. The standard deviation of the p-values for the ES results are displayed in Figure 12.

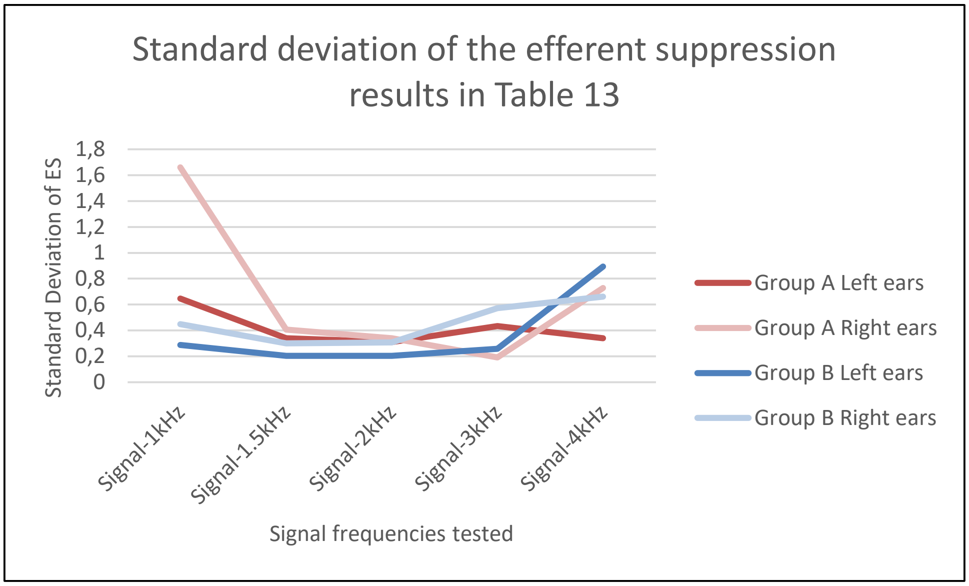

Figure 12: Standard deviation of the p-values for the efferent suppression results

The results of the standard deviation of the ES of Group A are presented in red - the results of the left ears in dark red and the results of right ears of the participants in light red. The results of the standard deviation of the ES of the participants from Group B are presented in blue - the results of the left ears in dark blue and the results of the right ears in light blue. All ES results measured in the left ears of the participants from Group A were higher than the ES results measured in the left ears of Group B, the group with minimal HL, at frequencies 1000 Hz, 1500 Hz, 2000 Hz, and 3000 Hz, but not 4000 Hz. All ES results measured for the right ears of participants from Group A, the normal hearing group, were higher than the ES results measured in the right ears of participants from Group B, the group with minimal HL, at frequencies 1000 Hz, 1500 Hz, 2000 Hz, and 4000 Hz, but not 3000 Hz. Therefore, the participants with normal hearing presented with a slightly stronger MOC reflex than the participants with a minimal HL for both the left and the right ears included in the study.

In conclusion, although there was no statistically significant difference (p-value less than 0.05) found between the results of the ears of the participants from group A compared to those of group B, the standard deviation values obtained for the ES results indicated that the normal hearing participants recorded a higher ES than the participants with a minimal HL at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz. The higher ES results of the normal hearing participants were confirmed when results from the left and right ears were combined and compared to the standard deviation of the ES obtained for the combined results from participants in group B at all frequencies (1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz).

5. Chapter 5: Discussion of results

5.1. Introduction to discussion of results

The main aim of the study was to determine the relationship between the MOC efferent reflex strength and susceptibility to NIHL.

The results gathered in this study show the same trend as those from previous research by Kumar et al., (2013A) who found significant differences in the TEOAE amplitude results after short duration exposure to broad band noise. Kumar et al., (2013A) measured the results of the TEOAE amplitudes before and after noise exposure in 20 participants. Results indicated that there was a statistically significant reduction in the amplitude of the TEOAE results between pre- and post-noise exposure conditions with a higher reduction at 3000 Hz and 4000 Hz (Kumar et al., 2013A).

One of the reasons that no significant difference was found between the participants with normal hearing and participants with minimal permanent HL in the current study could be that the pure-tone threshold differences between the two groups may not have been large enough. The average difference in pure-tone thresholds between groups A and B at frequencies of 3000 Hz, 4000 Hz and 6000 Hz was only 10 dB at each frequency. The participants of group B presented with minimal HL only. The reason for this selection criterion was to ensure present and reliable OAEs in both groups (Katz et al., 2015). Accurate and reliable OAE recordings would be difficult to achieve or would have been absent if participants with a moderate HL of 40 to 60 dB at the high frequencies had been selected.

5.2. Discussion of the ES results in the left and right ears

The ES results from the normal-hearing ears were compared to those from the ears with minimal HL using first the results of the left and the right ears combined, then only the left ears were compared and then the right ears were compared separately between the two participant groups. The ES of 36 normal-hearing ears was compared to the ES of 26 ears with a minimal HL at each tested frequency for the left and the right ears combined. Percentage-wise, 28% more ears were used for the normal-hearing group than for the group with minimal HL. If more ears from the group with minimal HL were involved, a lower p-value might have been calculated.

When the average ES was calculated using all frequencies at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz, a 0.765 average ES was calculated in the left ears and a 0.699 average ES was calculated in the right ears. The participants in this study therefore presented with a slightly stronger MOCR in the right ears than the left ears using the average of all frequencies, but in contrary when only using 4000 Hz the ES of the lefts ears (0.130) are stronger than the right ears (0.814). The MOCR has been reported to be stronger in the right ears compared to the left ear in others studies, but many contradictory studies have shown different results depending on the methodological differences (Perrot et al., 1999; Otsuka et al., 2016).

The lowest p-values were recorded at 4000 Hz in the left ears (0.130), and at 2000 Hz (0.276) when the left and right ears were combined. Research has confirmed that 2000 Hz and 4000 Hz are frequencies often affected by noise exposure. Ristovska et al., (2015) found that 68.2% of their participants who had been exposed to noise presented with a notch at either 2000 Hz or 4000 Hz. In the current study, participants from both groups A and B had to present with an average hearing threshold between 0 and 15 dB for frequencies 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. If 2000 Hz had been excluded from the criteria, more participants could have been included for the group with minimal HL.

5.3. Discussion of the comparison of the ES results between participant groups for different age categories

The ES results were compared after separating the participants into three age categories. For the age category 30 to 35 years 36 ears were available, 27 for group A and only 9 for group B. For the age category 36 to 40 years 11 ears were available, 7 for group A and 4 for group B. For the age category 41 to 45 years 15 ears were available, only 2 for group A and 13 for group B. For the youngest age category (30 to 35 years) there were three times more participants from the normal-hearing group (A) than from the group with minimal HL (B), but fewer participants (6 times less) from the normal-hearing group could be used for the older age category of 41 to 45 years than from the group with minimal HL. The older the workers are, the longer their history of noise exposure might be and the more co-morbidities may be present to restrict them from being participants with regard to the criteria of the study.

The lowest p-values were calculated again at 2000 Hz and 4000 Hz, with a p-value of 0.085 at 4000 Hz for the age category 30 to 35 years and a p-value of 0.086 at 2000 Hz for the age category 41 to 45 years. If more participants were included in group B for the age group 30 to 35 years and more participants for group A in the age group of 41 to 45 years, a more accurate p-value could have been calculated. From all the ES results compared in the results of this study these two p-values were the lowest and closest to the 0.05 (5%) level of significance.

5.4. Discussion of the results according to years of noise exposure

A comparison was made using only participants who have a history of noise exposure of 10 years or more to determine if the participants who presented with normal hearing thresholds after 10 years or more of noise exposure have a stronger MOC than the participants who presented with a minimal HL after the same duration of noise exposure. A total of 18 ears were used with 9 ears from group A and 9 ears from group B.

The lowest p-value was recorded at 4000 Hz (0.474) with the calculated p-values at frequencies 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz showing a gradual decreasing slope as displayed in Figure 11. This slope correlates with a typical NIHL audiogram slope with normal low frequency thresholds and a decreasing slope in hearing thresholds at the higher frequencies. This indicates that the effect of noise is more significant in the basal region of the cochlea.

5.5. Conclusion of discussion

The results of a study by Otsuka et al., (2016) provided evidence that the MOC reflex strength may be used to predict the degree of the TTS. However, the results were only significant for the ipsilateral MOC reflex and not for the contralateral MOC reflex. De Souza et al., (2013) found that their group of participants who had been exposed to noise presented with lower suppression effects than the non-exposed group. Keppler et al., (2014) concluded that the results from contralateral suppression of TEOAEs and DPOAEs could not predict an individual’s susceptibility to temporary HL. Wolpert et al., (2014) measured the contralateral suppression of DPOAEs and compared the results to the TTS of each participant. The measurements used in the study showed a statistically significant correlation between the TTS and the contralateral suppression of the OAEs.

These researchers all concluded that OAEs might indicate the accumulated damage to the inner ear before a HL is recorded, and confirmed that the MOC reflex was reduced in individuals who experienced NIHL. It was recommended in all the studies that more research be conducted on the MOC reflex and PTS with both TEOAE and DPOAE measurements. Another study by Mertes and Leek in 2016 compared the contralateral suppression of TEOAE's and auditory steady state responses (ASSR). TEOAE's are difficult to record or absent in participants who present with a moderate to severe hearing loss and an alternative to measuring contralateral suppression in these participants could be ASSR's because they are measureable in many degrees of hearing loss. Although the magnitude of the contralateral suppression of the ASSR's were recorded larger than the contralateral suppression of the TEOAE's, no significant difference was recorded. It was recommended for more research to be done on the contralateral suppression of ASSR's and the MOC (Mertes & Leek, 2016).

The crucial question is whether the ES results can be used in clinical practice to identify or predict which individuals would be more prone to developing HL. In the current study, the normal hearing participants did present on average with a stronger ES than participants with minimal HL, but no statistically significant difference could be recorded. The issue is raised whether these findings are strong enough to take preventative measures for these individuals with a strong ES to avoid developing a HL in the future. There were participants from group B who presented with the same degree of minimal HL but recorded different ES results, some stronger and some weaker ES.

The findings of this study are not significant enough to use in clinical practice to predict if an individual with a weaker ES could develop a HL. Conclusions from previous studies show no consistency in the correlation between the strength of the MOC and susceptibility to hearing loss and therefore questions the protective role of the MOC to acoustic trauma.

NIHL is a permanent disability and not a curable disease. It can, however, be prevented. Controlled monitoring in audiometry for all individuals exposed to noise remains essential, and the need for continuous research remains imperative.

6. Chapter 6: Conclusion

A discussion of the clinical implications and limitations, positive aspects of the study and recommendations for further research follows below.

6.1. Clinical implications and limitations

- All OAE testing was conducted in a quiet room and not in a soundproof booth. Due to the size of the audio booth used at the mine, it was not possible to fit the participant, audiologist and equipment into the booth. Although all the participants were tested in the same manner, and noise levels were monitored at all times, it is possible that some of the OAE results could have been influenced by background noise.
- Many possible participants presented with middle ear pathologies and therefore could not be used as participants for data collection. The high prevalence of middle ear pathology in the mining industry could be a result of the pressure changes the employees undergo when being transported underground to the shafts at a rapid speed on a daily basis (Walling, 2000). The high prevalence of middle ear pathology in the mining industry could also be related to environmental factors.
- Many possible participants presented with earwax plugs and therefore could not be used as participants for data collection. Earwax plugs are very common in the mining industry and constant use of the insert earplugs for long periods of time may cause earwax to build up and block the normal flow of earwax (Katz et al., 2015).
- The presence of tinnitus was not investigated before the study and therefore participants with possible tinnitus were included in the study, and some of the participants could have experienced tinnitus at the time of testing. The presence of tinnitus might be the reason for the

absent or low OAE results and could have affected the outcome of the data analysis (Qasem et al., 2010).

- The differences between group A and group B in the pure tone thresholds recorded was on average only 10 dB. This is a very small difference between the normal hearing group and the group with minimal HL, and more accurate ES differences could have been recorded if a larger difference in the pure tone thresholds were present. A 10 dB difference could also be a result of inter-test variance and cannot be seen as a true difference (Katz et al., 2015).
- Unfortunately, accurate noise exposure histories of the participants were not available. For a more accurate comparison of the results, it is recommended that an in-depth evaluation of the noise exposure history should be done.

6.2. Positive aspects of the study

The listed limitations should not detract from the value of the study and its potential to provide a constructive contribution to the body of research on the topic of predicting NIHL. A good probe stability of 99% or more was present during all OAE measurements. This can contribute to accurate measurements. Strong inclusion and exclusion criteria were used regarding participant selection. Testing procedures were also conducted in a reliable and consistent manner throughout the data collection.

The contralateral suppression of TEOAEs is an objective and non-invasive test that can be measured in a short time, which makes it convenient and feasible for organisations and companies to use.

Although no statistically significant difference was measured, the clinical value of this study is that a slightly stronger ES was measured for participants with normal hearing compared to the ES obtained for participants with minimal hearing loss. This suggests that it may well be possible to predict if an individual is more susceptible to developing a hearing loss due to noise exposure by using the contralateral suppression of TEOAE measurements.

6.3. Recommendations for further research

An ideal study to measure the susceptibility to HL would be to commit to a 5 to 10-year study where an OAE baseline measurement with contralateral suppression could be recorded using similar protocols on normal hearing participants who are novices applying for an occupation with significant noise exposure, and who have no previous exposure to occupational noise. After 5 to 10 years of noise exposure, OAE recordings could be measured in the same participants. The results from those participants who have developed a more severe HL could be compared to the results from those who have maintained normal to near-normal hearing. This method will, however, be very time-consuming and the feasibility of such a study should be taken into account.

There is very limited research available on the contralateral suppression of OAEs and the measurement of the MOC reflex. It is recommended that more research be done on contralateral suppression of TEOAE, DPOAE and ASSR measurements in participants with permanent HL and present OAE recordings. A larger sample group is recommended with stringent selection criteria and a more accurate noise exposure history of the participants. An in-depth tinnitus questionnaire should be completed before data collection and participants with bothersome tinnitus should be excluded from the study to ensure more reliable results. It is also recommended that participants who present with a minimal to moderate hearing loss be selected for Group B, to create a larger average difference in hearing thresholds between the two groups. If contralateral suppression of ASSR’s are used instead of OAE’s as suggested by Mertes and Leek (2016) then participants with more severe degrees of hearing loss can be used for Group B. Data collection should include information that would allow the researcher to investigate the reason why some participants presented with a stronger ES than other participants.

6.4. Final statement

No statistically significant difference between the ES in normal hearing participants and in participants with minimal HL could be detected. However, the participants with normal hearing presented with a slightly stronger ES than the participants with a minimal HL. The conclusion of this study therefore indicates that the null hypotheses is true and that the contralateral suppression of TEOAEs cannot be used to predict the susceptibility of an individual to NIHL.

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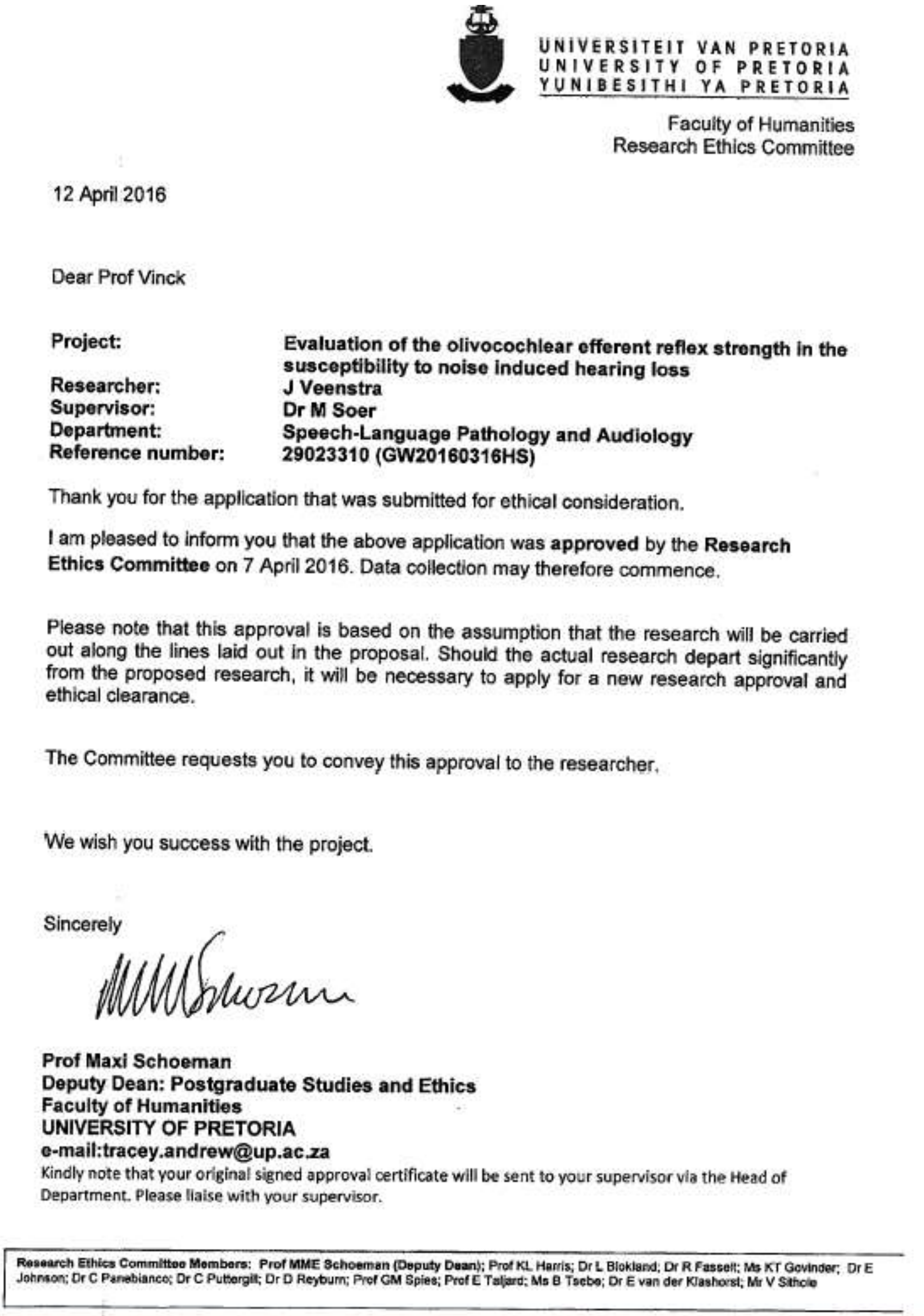
Appendices

Appendix A: Ethical Clearance



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

12 April 2016

Dear Prof Vinck

Project:	**Evaluation of the olivocochlear efferent reflex strength in the susceptibility to noise induced hearing loss**
Researcher:	**J Veenstra**
Supervisor:	**Dr M Soer**
Department:	**Speech-Language Pathology and Audiology**
Reference number:	**29023310 (GW20160316HS)**

Thank you for the application that was submitted for ethical consideration.

I am pleased to inform you that the above application was **approved** by the **Research Ethics Committee** on 7 April 2016. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

The Committee requests you to convey this approval to the researcher.

We wish you success with the project.

Sincerely

Prof Maxi Schoeman
Deputy Dean: Postgraduate Studies and Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail:tracey.andrew@up.ac.za

Kindly note that your original signed approval certificate will be sent to your supervisor via the Head of Department. Please liaise with your supervisor.

Appendix B: Informed consent to participants

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Dear Participant

REQUEST FOR PARTICIPATION IN A RESEARCH STUDY

This letter is to request participation in a research study to investigate the relationship between contralateral suppression of otoacoustic emissions and noise induced hearing loss.

Participation in this study is completely voluntary and participants may withdraw from the study at any time without any negative consequences. Participation in the study does not pose any risk to participants. The results from the research will have no influence on compensation or fitness for work.

All identifying information of participants will be kept confidential. The data gathered will be kept for 15 years for archiving and research purposes before being destroyed. The data obtained will be available to the supervisor, Dr M. Soer and consultant, Dr E. de Koker. All the relevant results will be compiled in a research report, which will be available at the University of Pretoria. Participants may also request to view the results obtained.

During your appointment testing will take place as with diagnostic audiometry. One additional test will be done for the purpose of the research that will measure the functioning of the olivocochlear efferent auditory system. During the testing procedure it will be explained how each test is done and what is expected from you. At the end of the appointment the results for each test will be shown and explained.

Your participation will be greatly appreciated.

Yours sincerely,

J.Veenstra.

Jomari Veenstra
(Researcher)

Dr Elize de Koker
(Consultant)

☐ Yes, I would like to be a participant in the research study.

☐ No, I would not like to be a participant in the research study.

Signature	Company number	Date

Appendix C: Informed consent to management at the mine

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

To: Lonmin Mine
From: Jomari Veenstra (Researcher and Audiologist)
Date: 15 October 2015

REQUEST TO USE WORKERS AT LONMIN FOR A RESEARCH STUDY

This letter is to request participation from workers in Marikana Lonmin Mine in a research study to investigate the relationship between contralateral suppression of otoacoustic emissions and noise induced hearing loss.

Participation in this study is completely voluntary and participants may withdraw from the study at any time without any negative consequences. Participation in the study does not pose any risk for participants. The results from the research will have no influence on compensation or the fitness of the participants. Participants will be used from the Occupational Health Centre on the same day as their6 monthly or annual medical screening; therefore no extra working shift will be used for participation in the study.

All identifying information of participants will be kept confidential. The data gathered will be kept for 15 years for archiving and research purposes before being destroyed. The data obtained will be available to the supervisor, Dr M. Soer and consultant, Dr E. de Koker. All the relevant results will be compiled in a research report, which will be available at the University of Pretoria. Lonmin may also request to view the results obtained.

The testing will take place as with diagnostic audiometry. One additional test will be done for the purpose of the research that will measure the functioning of the olivocochlear efferent auditory system. At the end of the appointment the results for each test will be shown and explained.

At the end of the study Lonmin may request a research report. The use of workers at Lonmin Mine will be greatly appreciated.

Yours sincerely,

J Veenstra

Jomari Veenstra

(Researcher)

Dr Elize de Koker

(Consultant)

☒ Yes, I allow Jomari Veenstra to commence with the research study.

☐ No, I do not allow Jomari Veenstra to commence with the research study.

subject to approval by ethics committee of UP

16 October 2015

Dr. Marie Vermaak
(Senior Manager Occupational Health of Lonmin Mine)
Contact number: 014 571 4564
Email address: marie.vermaak@lonmin.com

Date

☑ Yes, I allow Jomari Veenstra to commence with the research study.

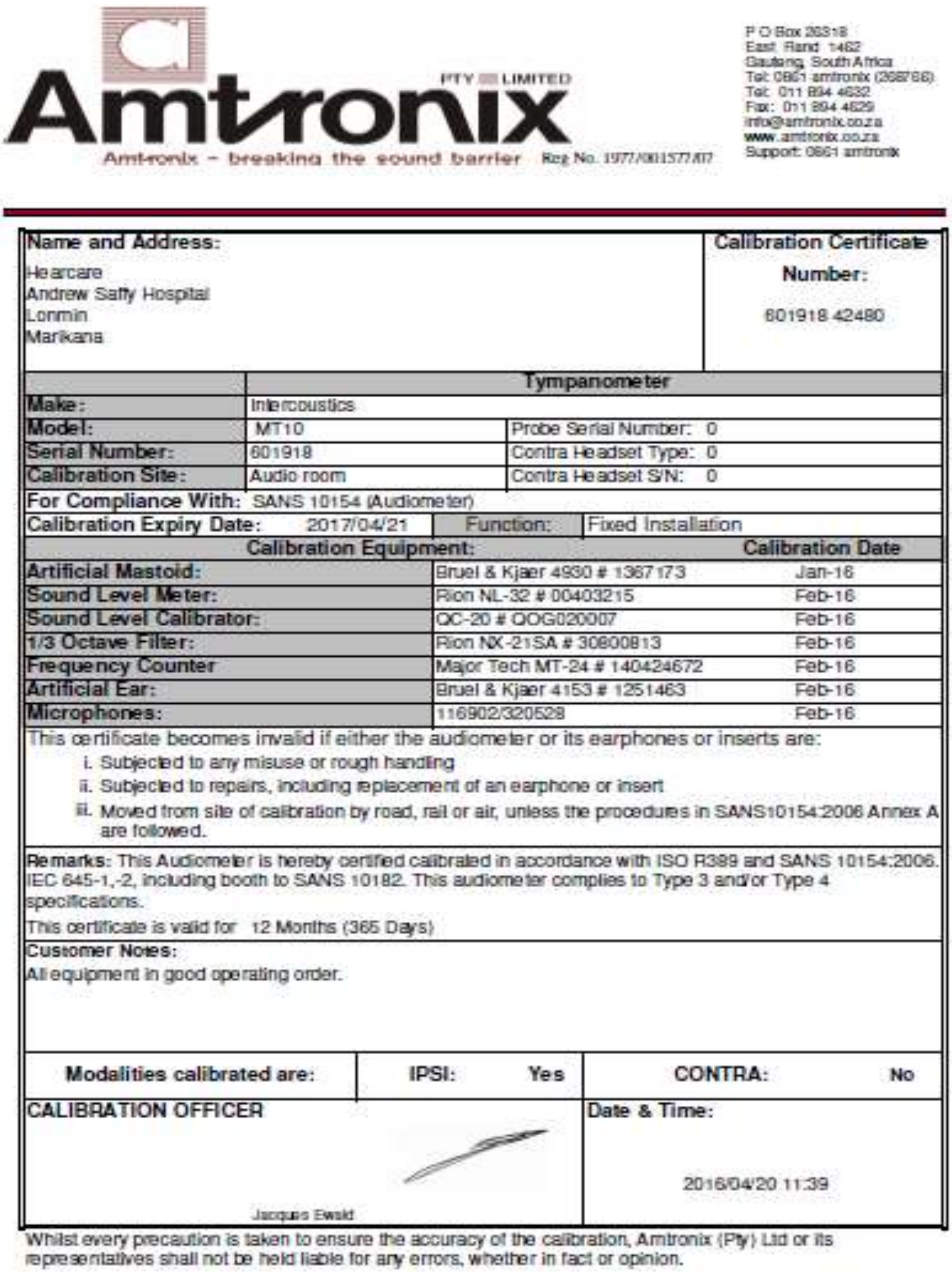
☐ No, I do not allow Jomari Veenstra to commence with the research study.

16 October 2015

Dr. Ntomboxolo Dudumayo
(Medical Practitioner)
Contact number: 014 571 4469
Email address: Ntomboxolo.dudumayo@lonmin.com

Date

Appendix D: Calibration Certificate of Tympanometer



Amtronix PTY LIMITED

Amtronix - breaking the sound barrier Reg No. 1977/001577/07

P O Box 26318
East Rand 1462
Gauteng, South Africa
Tel: 0861 amtronix (268766)
Tel: 011 894 4632
Fax: 011 894 4629
info@amtronix.co.za
www.amtronix.co.za
Support: 0861 amtronix

Name and Address: Hearcare Andrew Saffy Hospital Lonmin Marikana	**Calibration Certificate Number:** 601918 42480

	Tympanometer	
Make:	Intercoustics	
Model:	MT10	Probe Serial Number: 0
Serial Number:	601918	Contra Headset Type: 0
Calibration Site:	Audio room	Contra Headset S/N: 0

For Compliance With: SANS 10154 (Audiometer)

Calibration Expiry Date:	2017/04/21	Function:	Fixed Installation

Calibration Equipment:		**Calibration Date**
Artificial Mastoid:	Bruel & Kjaer 4930 # 1367173	Jan-16
Sound Level Meter:	Rion NL-32 # 00403215	Feb-16
Sound Level Calibrator:	QC-20 # QOG020007	Feb-16
1/3 Octave Filter:	Rion NX-21SA # 30800813	Feb-16
Frequency Counter	Major Tech MT-24 # 140424672	Feb-16
Artificial Ear:	Bruel & Kjaer 4153 # 1251463	Feb-16
Microphones:	116902/320528	Feb-16

This certificate becomes invalid if either the audiometer or its earphones or inserts are:

i. Subjected to any misuse or rough handling
ii. Subjected to repairs, including replacement of an earphone or insert
iii. Moved from site of calibration by road, rail or air, unless the procedures in SANS10154:2006 Annex A are followed.

Remarks: This Audiometer is hereby certified calibrated in accordance with ISO R389 and SANS 10154:2006. IEC 645-1,-2, including booth to SANS 10182. This audiometer complies to Type 3 and/or Type 4 specifications.

This certificate is valid for 12 Months (365 Days)

Customer Notes:

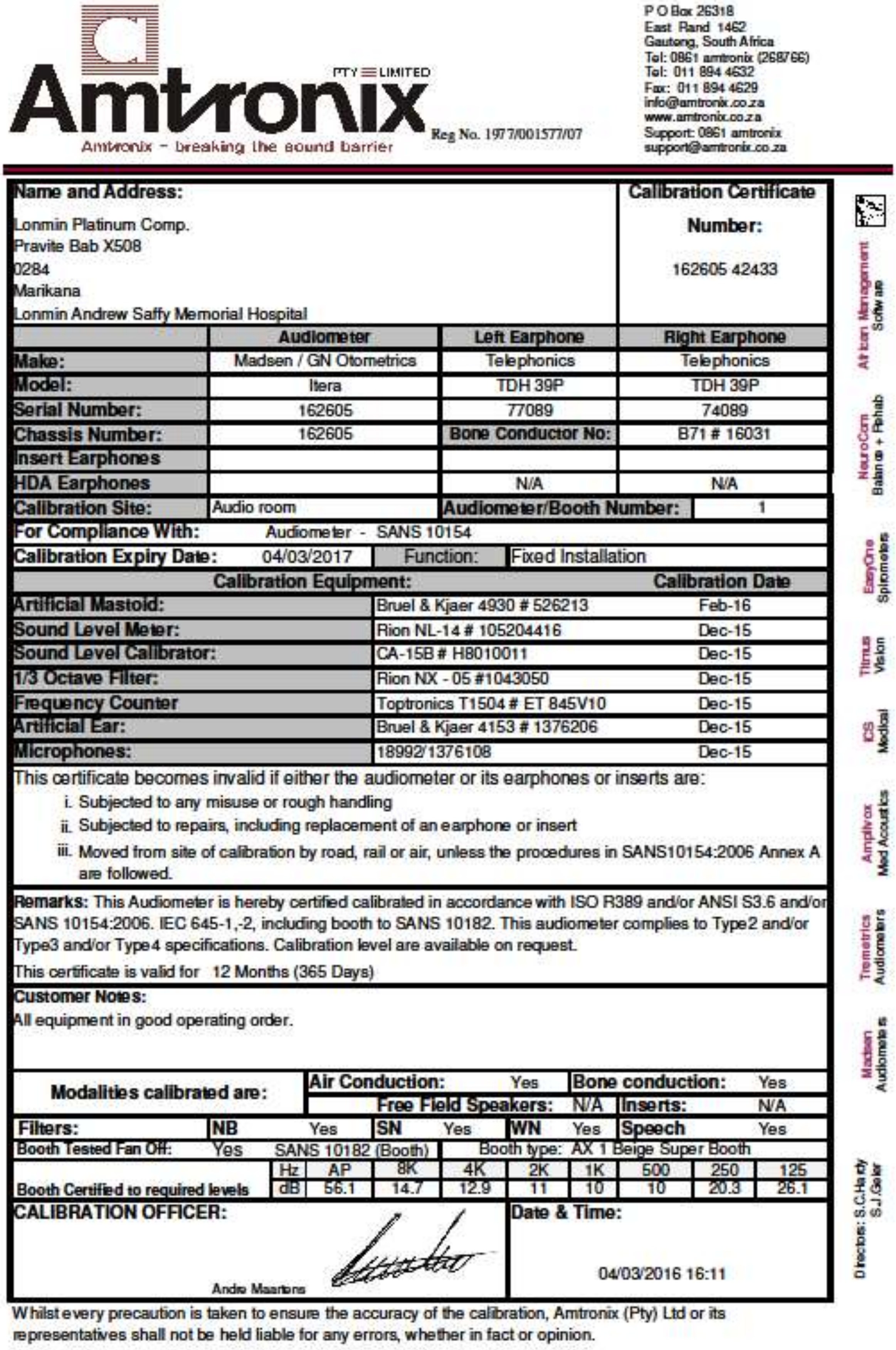
All equipment in good operating order.

Modalities calibrated are:	**IPSI:**	**Yes**	**CONTRA:**	**No**

CALIBRATION OFFICER Jacques Ewald	**Date & Time:** 2016/04/20 11:39

Whilst every precaution is taken to ensure the accuracy of the calibration, Amtronix (Pty) Ltd or its representatives shall not be held liable for any errors, whether in fact or opinion.

Appendix E: Calibration certificate of audiometer



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info@amtronix.co.za
www.amtronix.co.za
Support: 0861 amtronix
support@amtronix.co.za

Name and Address:

Lonmin Platinum Comp.
Pravite Bab X508
0284
Marikana
Lonmin Andrew Saffy Memorial Hospital

Calibration Certificate Number: 162605 42433

	Audiometer	**Left Earphone**	**Right Earphone**
Make:	Madsen / GN Otometrics	Telephonics	Telephonics
Model:	Itera	TDH 39P	TDH 39P
Serial Number:	162605	77089	74089
Chassis Number:	162605	**Bone Conductor No:**	B71 # 16031
Insert Earphones			
HDA Earphones		N/A	N/A

Calibration Site: Audio room **Audiometer/Booth Number:** 1

For Compliance With: Audiometer - SANS 10154

Calibration Expiry Date: 04/03/2017 Function: Fixed Installation

Calibration Equipment:		**Calibration Date**
Artificial Mastoid:	Bruel & Kjaer 4930 # 526213	Feb-16
Sound Level Meter:	Rion NL-14 # 105204416	Dec-15
Sound Level Calibrator:	CA-15B # H8010011	Dec-15
1/3 Octave Filter:	Rion NX - 05 #1043050	Dec-15
Frequency Counter	Toptronics T1504 # ET 845V10	Dec-15
Artificial Ear:	Bruel & Kjaer 4153 # 1376206	Dec-15
Microphones:	18992/1376108	Dec-15

This certificate becomes invalid if either the audiometer or its earphones or inserts are:

- i. Subjected to any misuse or rough handling
- ii. Subjected to repairs, including replacement of an earphone or insert
- iii. Moved from site of calibration by road, rail or air, unless the procedures in SANS10154:2006 Annex A are followed.

Remarks: This Audiometer is hereby certified calibrated in accordance with ISO R389 and/or ANSI S3.6 and/or SANS 10154:2006. IEC 645-1,-2, including booth to SANS 10182. This audiometer complies to Type2 and/or Type3 and/or Type4 specifications. Calibration level are available on request.

This certificate is valid for 12 Months (365 Days)

Customer Notes:

All equipment in good operating order.

Modalities calibrated are:	**Air Conduction:**	Yes	**Bone conduction:**	Yes
	Free Field Speakers:	N/A	**Inserts:**	N/A

Filters:	**NB**	Yes	**SN**	Yes	**WN**	Yes	**Speech**	Yes

Booth Tested Fan Off: Yes SANS 10182 (Booth) Booth type: AX 1 Beige Super Booth

Booth Certified to required levels	Hz	AP	8K	4K	2K	1K	500	250	125
	dB	56.1	14.7	12.9	11	10	10	20.3	26.1

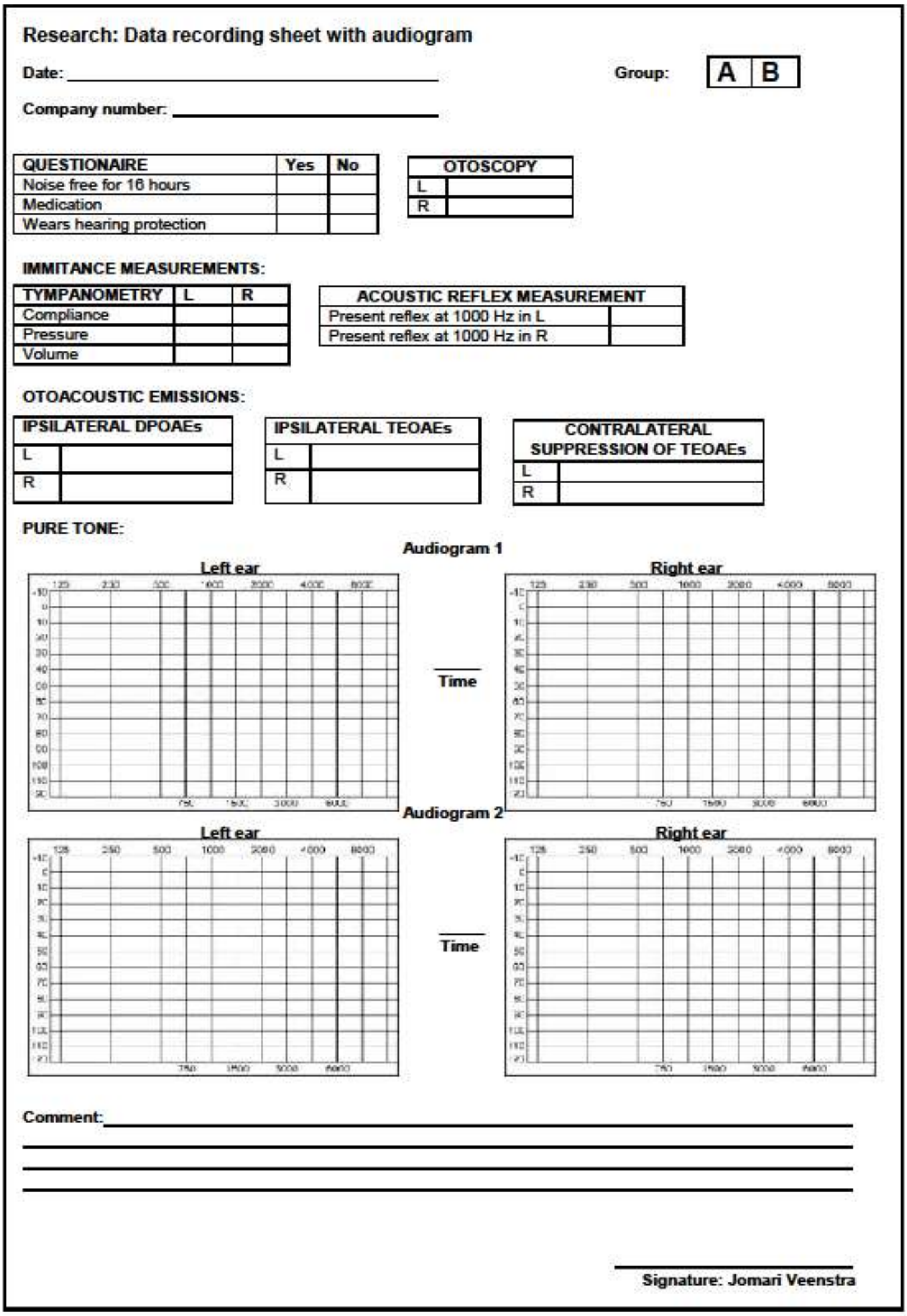
CALIBRATION OFFICER: Andre Maartens

Date & Time: 04/03/2016 16:11

Whilst every precaution is taken to ensure the accuracy of the calibration, Amtronix (Pty) Ltd or its representatives shall not be held liable for any errors, whether in fact or opinion.

African Management Software
NeuroCom Balance + Rehab
EasyOne Spirometers
Titmus Vision
ICS Medical
Amplivox Med Acoustics
Tremetrics Audiometers
Madsen Audiometers
Directors: S.C.Hardy S.J.Geier

Appendix F: Data recording sheet with audiogram



Research: Data recording sheet with audiogram

Date: ____________________

Group: A | B

Company number: ____________________

QUESTIONAIRE	Yes	No
Noise free for 16 hours		
Medication		
Wears hearing protection		

OTOSCOPY	
L	
R	

IMMITANCE MEASUREMENTS:

TYMPANOMETRY	L	R
Compliance		
Pressure		
Volume		

ACOUSTIC REFLEX MEASUREMENT	
Present reflex at 1000 Hz in L	
Present reflex at 1000 Hz in R	

OTOACOUSTIC EMISSIONS:

IPSILATERAL DPOAEs	
L	
R	

IPSILATERAL TEOAEs	
L	
R	

CONTRALATERAL SUPPRESSION OF TEOAEs	
L	
R	

PURE TONE:

Audiogram 1

Left ear — **Right ear**

Time

Audiogram 2

Left ear — **Right ear**

Time

Comment: ____________________

Signature: Jomari Veenstra

Appendix G: Pilot study results

ID Number	DateOfBirth	Gender	DateOfTest	TimeOfTest	Ear	TestDuratio	StimulusInt	ResponseL	NoiseLevel	StimulusSt	Reproduci	LoNoiseCo	HiNoiseCo
Pilot 01	1974/06/01	Male	2016/10/12	8:17:20 AM	Left	61	81,6	6,6	3	100	75	260	18
Pilot 01	1974/06/01	Male	2016/10/12	8:17:20 AM	Right	61	79,2	4,5	10,3	100	11	260	18
Pilot 01	1974/06/01	Male	2016/10/12	8:22:33 AM	Left	119	81,7	13,4	2,8	99	93	270	1
Pilot 01	1974/06/01	Male	2016/10/12	8:22:33 AM	Left	119	66,7	13,3	2,6	99	93	261	2
Pilot 01	1974/06/01	Male	2016/10/12	8:25:37 AM	Right	117	79,8	13,6	-2,1	99	98	262	0
Pilot 01	1974/06/01	Male	2016/10/12	8:25:37 AM	Right	117	69,2	13,5	-2,5	99	98	261	3
Pilot 02	1967/01/01	Male	2016/10/12	8:44:50 AM	Left	60	76,8	1,7	3,4	100	42	260	2
Pilot 02	1967/01/01	Male	2016/10/12	8:44:50 AM	Right	60	78,9	-4	6,1	100	1	260	2
Pilot 02	1967/01/01	Male	2016/10/12	8:48:59 AM	Left	119	78,5	15,7	2,9	99	95	267	7
Pilot 02	1967/01/01	Male	2016/10/12	8:48:59 AM	Left	119	64,5	15,5	2,7	99	95	261	6
Pilot 02	1967/01/01	Male	2016/10/12	8:51:53 AM	Right	119	79,4	10,3	3,7	99	84	266	8
Pilot 02	1967/01/01	Male	2016/10/12	8:51:53 AM	Right	119	66,7	10,7	2,6	99	89	261	8
Pilot 03	1954/03/19	Male	2016/10/12	9:25:35 AM	Left	62	78,2	-8,8	1,3	100	20	260	26
Pilot 03	1954/03/19	Male	2016/10/12	9:25:35 AM	Right	62	80,4	-50	9,2	100	-23	260	26
Pilot 03	1954/03/19	Male	2016/10/12	9:29:58 AM	Left	118	78,9	4,6	-2,4	100	91	265	9
Pilot 03	1954/03/19	Male	2016/10/12	9:29:58 AM	Left	118	65,6	4,6	-2,7	100	92	261	2
Pilot 03	1954/03/19	Male	2016/10/12	9:33:25 AM	Right	124	80,8	8,3	4,1	99	72	267	25
Pilot 03	1954/03/19	Male	2016/10/12	9:33:25 AM	Right	124	68,4	8,1	4,6	99	68	261	31
Pilot 04	1979/07/03	Male	2016/10/12	9:55:36 AM	Left	61	77,1	2,2	2,2	100	48	260	11
Pilot 04	1979/07/03	Male	2016/10/12	9:55:36 AM	Right	61	76,8	1,1	0,8	100	55	260	11
Pilot 04	1979/07/03	Male	2016/10/12	10:00:00 AM	Left	119	77,7	9,5	-4,2	99	96	268	5
Pilot 04	1979/07/03	Male	2016/10/12	10:00:00 AM	Left	119	69,9	9,3	-2,7	99	95	261	9
Pilot 04	1979/07/03	Male	2016/10/12	10:03:07 AM	Right	118	77,1	9,7	-2,2	99	96	267	5
Pilot 04	1979/07/03	Male	2016/10/12	10:03:07 AM	Right	118	68,4	9,6	-2,6	99	96	261	3
Pilot 05	1963/06/11	Male	2016/10/12	10:50:30 AM	Left	59	80,2	0,2	1,9	100	39	260	0
Pilot 05	1963/06/11	Male	2016/10/12	10:50:30 AM	Right	59	76,8	-50	0,8	100	27	260	0
Pilot 05	1963/06/11	Male	2016/10/12	10:54:46 AM	Left	118	80,2	6,8	-3,5	100	94	267	4
Pilot 05	1963/06/11	Male	2016/10/12	10:54:46 AM	Left	118	66,7	7	-3,2	100	93	261	0
Pilot 05	1963/06/11	Male	2016/10/12	10:57:48 AM	Right	118	77,4	6,3	-3,3	99	94	261	10
Pilot 05	1963/06/11	Male	2016/10/12	10:57:48 AM	Right	118	68,4	6	-4,4	99	95	263	0

Signal-1kHz	Signal-1.5k	Signal-2kHz	Signal-3kHz	Signal-4kHz	Noise-1kHz	Noise-1.5k	Noise-2kHz	Noise-3kHz	Noise-4kHz	ES 1k	ES 1.5k	ES 2k	ES 3k	ES 4k
3,5	1,7	-2,8	-4,7	-7,9	-11,1	-8,1	-8,2	-5,2	-6,7	14,6	9,8	5,4	0,5	-1,2
-7,9	-1,8	-6,9	3,3	-4	-2,6	-2,2	5,1	3,1	-3,3	-5,3	0,4	-12	0,2	-0,7
7,7	10,5	5,9	-0,8	-10,1	-8,5	-12,6	-9,9	-9,4	-11,4	16,2	23,1	15,8	8,6	1,3
7,9	10,4	5,4	-1,7	-10,6	-9,4	-9,1	-10,2	-9,7	-11,5	17,3	19,5	15,6	8	0,9
10,2	9	6,2	-4,1	-9,5	-12,8	-16,1	-12,7	-11,8	-11,8	23	25,1	18,9	7,7	2,3
10,2	8,7	6,2	-4,4	-10	-12,4	-15,9	-15,1	-13,3	-10,5	22,6	24,6	21,3	8,9	0,5
-6,7	-6,7	-13,5	-1,4	-4,7	-6,9	-6,7	-6,4	-6,4	-5,4	0,2	0	-7,1	5	0,7
-10,6	-8,7	-5,4	-4	-7,2	-3,3	-3,4	-4,5	-8,5	-5,1	-7,3	-5,3	-0,9	4,5	-2,1
13	11,5	-1,2	1,8	-1,8	-5,4	-4,3	-12,8	-13,2	-11,9	18,4	15,8	11,6	15	10,1
12,7	11,4	-1,2	2	-1,7	-3,6	-6,6	-9	-11,7	-10,3	16,3	18	7,8	13,7	8,6
6	3,9	5,3	-2	-5,6	-8,9	-3,8	-10,9	-10	-9,1	14,9	7,7	16,2	8	3,5
7	3,5	5,3	-1,1	-5,7	-4,6	-4,2	-9,1	-10,8	-10,2	11,6	7,7	14,4	9,7	4,5
-13,4	-8,8	-12,4	-9,5	-8,5	-12,5	-10,8	-9,2	-7,2	-3,9	-0,9	2	-3,2	-2,3	-4,6
-30	-14,2	-9,4	-10,3	-12,7	-0,2	3,5	2,7	-5,1	-4,3	-29,8	-17,7	-12,1	-5,2	-8,4
-1,4	2,3	-11,9	-9	-5,9	-15,1	-13,3	-15,4	-11,2	-10,4	13,7	15,6	3,5	2,2	4,5
-0,8	1,9	-11,9	-8,6	-5,3	-11	-14,8	-15,6	-11,7	-10,8	10,2	16,7	3,7	3,1	5,5
4,6	3,4	1,3	-12,6	-7	-5,7	-4	-5,2	-13,4	-7,9	10,3	7,4	6,5	0,8	0,9
5,2	2,8	-0,4	-16,7	-5,2	-4,2	-4,3	-1,9	-10,2	-10,2	9,4	7,1	1,5	-6,5	5
-8,6	-0,9	-4	-4,8	-9,2	-9,6	-10,3	-6,8	-7,5	-6,3	1	9,4	2,8	2,7	-2,9
-13,2	-2,9	-1,1	-6,5	-9,2	-9,7	-14,2	-12,4	-6,3	-6	-3,5	11,3	11,3	-0,2	-3,2
6,1	5,5	-1,6	-4,1	-8	-11,3	-14,3	-13,2	-11,9	-12,6	17,4	19,8	11,6	7,8	4,6
6	5,3	-2,5	-4,1	-7,9	-11,8	-14	-17,3	-9,8	-10,5	17,8	19,3	14,8	5,7	2,6
0,2	6,9	4,7	-3,3	-11,6	-13,4	-15	-13,1	-10,9	-10,9	13,6	21,9	17,8	7,6	-0,7
0	6,9	4,1	-3,7	-10,3	-11,9	-11,8	-15,3	-11,8	-11,7	11,9	18,7	19,4	8,1	1,4
-12,4	-15,6	-15,7	-2,5	-3,7	-14,2	-9,7	-5,1	-7,1	-5,1	1,8	-5,9	-10,6	4,6	1,4
-22,4	-13,8	-10,7	-7,5	-8,7	-11,2	-12,6	-7,6	-6,6	-6,2	-11,2	-1,2	-3,1	-0,9	-2,5
-1,6	2	-5,7	-0,4	1,1	-15,1	-8,4	-15,1	-14,2	-11,9	13,5	10,4	9,4	13,8	13
-2,3	2,6	-5,1	0,2	1,1	-12,4	-11,3	-14,5	-13,1	-9,5	10,1	13,9	9,4	13,3	10,6
3,9	-4,9	-4,1	-0,6	-7,6	-14,1	-13,6	-11,2	-10,6	-11,6	18	8,7	7,1	10	4
3,8	-4,6	-5,1	-1	-7,6	-15	-16,4	-15,8	-13,2	-9,7	18,8	11,8	10,7	12,2	2,1

Appendix H: TEOAE and efferent suppression results

Participant number	Group	TEOAE	Ear	Signal-1kHz	Signal-1.5kHz	Signal-2kHz	Signal-3kHz	Signal-4kHz
1	A	Ipsilateral	Left	7,2	10,3	11,4	3,5	7
1	A	Contralateral without noise	Left	11,2	11,5	13,2	5,2	8,1
1	A	Contralateral with noise	Left	10,7	11,4	13	5	8
1	A	Efferent Suppression	Left	0,5	0,1	0,2	0,2	0,1
1	A	Ipsilateral	Right	8,4	11,5	7,2	3,4	6,3
1	A	Contralateral without noise	Right	15,2	14,7	11,1	7,1	10,1
1	A	Contralateral with noise	Right	14,8	14,4	11	6,9	10,2
1	A	Efferent Suppression	Right	0,4	0,3	0,1	0,2	-0,1
2	B	Ipsilateral	Left	7,9	5,5	2,7	0,5	-0,9
2	B	Contralateral without noise	Left	13,9	14,6	10,8	4,1	0,7
2	B	Contralateral with noise	Left	13,7	14,5	10,9	3,8	0
2	B	Efferent Suppression	Left	0,2	0,1	-0,1	0,3	0,7
2	B	Ipsilateral	Right	5,1	2,8	3,8	1,1	-2,8
2	B	Contralateral without noise	Right	15,1	11,3	9,7	1,6	-4,4
2	B	Contralateral with noise	Right	14,9	11,3	9,4	1	-4,2
2	B	Efferent Suppression	Right	0,2	0	0,3	0,6	-0,2
3	A	Ipsilateral	Left	-3,5	7,7	6,8	8,4	8,6
3	A	Contralateral without noise	Left	8,9	15,8	11,8	9,9	9,9
3	A	Contralateral with noise	Left	8,6	15,9	11,9	9,6	9,9
3	A	Efferent Suppression	Left	0,3	-0,1	-0,1	0,3	0
3	B	Ipsilateral	Right	0,1	10,7	7,9	5,8	-0,1
3	B	Contralateral without noise	Right	19,1	14,3	10,5	8,3	0,8
3	B	Contralateral with noise	Right	19	14,2	10,5	8,1	1,4
3	B	Efferent Suppression	Right	0,1	0,1	0	0,2	-0,6
4	A	Ipsilateral	Left	6,8	10	5,6	7,7	5,3
4	A	Contralateral without noise	Left	10,4	10,1	5,5	6,3	5,6
4	A	Contralateral with noise	Left	10,5	9,9	5,7	5,7	5,1
4	A	Efferent Suppression	Left	-0,1	0,2	-0,2	0,6	0,5
4	A	Ipsilateral	Right	4,9	6,2	6,2	9,2	3,4
4	A	Contralateral without noise	Right	-11,3	4,2	8,4	10,8	5
4	A	Contralateral with noise	Right	-4,9	5,1	8,3	10,6	5,6
4	A	Efferent Suppression	Right	-6,4	-0,9	0,1	0,2	-0,6
5	B	Ipsilateral	Left	-4,6	5,8	4,8	-4,4	-6,1
5	B	Contralateral without noise	Left	2	6	14,1	4,7	4,1
5	B	Contralateral with noise	Left	2	5,5	14,3	4,8	4
5	B	Efferent Suppression	Left	0	0,5	-0,2	-0,1	0,1
5	B	Ipsilateral	Right	7,5	10,8	8,8	-1,3	1,4
5	B	Contralateral without noise	Right	7,6	11,7	10,7	-0,2	3,1
5	B	Contralateral with noise	Right	6,8	11,3	10,2	-0,7	3,1
5	B	Efferent Suppression	Right	0,8	0,4	0,5	0,5	0
6	B	Ipsilateral	Left	2,3	12,4	9,7	-4,2	-5,3

6	B	Contralateral without noise	Left	2,9	11,3	8,5	-5,5	-2,9
6	B	Contralateral with noise	Left	2,6	11	8,2	-5,5	-3,5
6	B	Efferent Suppression	Left	0,3	0,3	0,3	0	0,6
6	B	Ipsilateral	Right	12,4	21,3	11,2	3,4	-1
6	B	Contralateral without noise	Right	11,5	20,4	11,5	2,5	-0,1
6	B	Contralateral with noise	Right	11,2	20	11,5	1,7	-0,8
7	B	Ipsilateral	Left	6,5	6,8	-12,9	-11,1	-9,3
7	B	Contralateral without noise	Left	9,9	8,6	-3	-11,2	-5,5
7	B	Contralateral with noise	Left	9,1	7,9	-2,8	-11,1	-4,4
6	B	Efferent Suppression	Right	0,3	0,4	0	0,8	0,7
7	B	Ipsilateral	Right	8,3	11,4	-1,8	-8,3	-6,6
7	B	Contralateral without noise	Right	8,8	11,3	-1,1	-7,8	-1,9
7	B	Contralateral with noise	Right	9,1	10,7	-2,1	-6,5	-2,1
7	B	Efferent Suppression	Right	-0,3	0,6	1	-1,3	0,2
8	B	Ipsilateral	Left	4,5	3,4	-7,1	-9,2	-5,7
8	B	Contralateral without noise	Left	12,7	16,8	8,7	-6,7	-3,1
8	B	Contralateral with noise	Left	12	16,7	8,3	-7,7	-2,7
8	B	Ipsilateral	Right	3,7	-0,8	2,9	-5,2	-7,9
8	B	Contralateral without noise	Right	-5,2	14,1	21,9	-1	-4,5
8	B	Contralateral with noise	Right	-5,6	14,2	22	0	-4,8
9	A	Ipsilateral	Left	11,7	12,4	0,7	3	-3,2
9	A	Contralateral without noise	Left	16,5	12,6	4,8	3,8	0,5
9	A	Contralateral with noise	Left	16,4	12,1	4,4	4,1	0,3
9	A	Efferent Suppression	Left	0,1	0,5	0,4	-0,3	0,2
9	B	Ipsilateral	Right	17,7	11,1	16,3	-1,8	-7,6
9	B	Contralateral without noise	Right	20,4	12,1	16,7	-0,1	-3,1
9	B	Contralateral with noise	Right	20,2	12,1	16,7	-0,3	-3,5
9	B	Efferent Suppression	Right	0,2	0	0	0,2	0,4
10	A	Ipsilateral	Left	-0,5	2,3	-1	-6,7	-5,2
10	A	Contralateral without noise	Left	5,9	10,9	-0,1	-6,8	-6,7
10	A	Contralateral with noise	Left	4,1	10,7	-1,1	-8,3	-6,3
10	A	Efferent Suppression	Left	1,8	0,2	1	1,5	-0,4
10	A	Ipsilateral	Right	3,9	0,2	0,6	-6	-10
10	A	Contralateral without noise	Right	6,9	2	4,1	-5,5	-9,3
10	A	Contralateral with noise	Right	6,2	1,6	3,5	-6,1	-9,2
10	A	Efferent Suppression	Right	0,7	0,4	0,6	0,6	-0,1
11	B	Ipsilateral	Left	2,6	3,2	-9,9	-14,6	-11,7
11	B	Contralateral without noise	Left	5,3	8,8	2,2	-11,6	-14
11	B	Contralateral with noise	Left	4,2	8,6	2,3	-11,9	-14,9
11	A	Ipsilateral	Right	4	3,8	-6,3	-11	-4,7
11	A	Contralateral without noise	Right	5	6	-2,3	-7,1	-1,9
11	A	Contralateral with noise	Right	4,9	5,8	-2,3	-7,4	-2,4
12	A	Ipsilateral	Left	-4,1	-0,1	1,8	-3,6	-13,1
12	A	Contralateral without noise	Left	15	7,4	6,2	-2,4	-11,7

12	A	Contralateral with noise	Left	14,6	7,4	5,9	-2,6	-12,6
12	A	Ipsilateral	Right	-3,9	-6,2	-10	-6,6	-10
12	A	Contralateral without noise	Right	8,5	7,3	-0,8	-1,2	-15
12	A	Contralateral with noise	Right	7,7	7,7	-0,8	-1,3	-13,5
13	A	Ipsilateral	Left	11,9	13	14,5	9,7	2,8
13	A	Contralateral without noise	Left	14	13,1	17,2	10,3	3,5
13	A	Contralateral with noise	Left	13,8	12,9	17	10	3,6
13	A	Efferent Suppression	Left	0,2	0,2	0,2	0,3	-0,1
13	A	Ipsilateral	Right	13,7	12	7,5	10,1	0,8
13	A	Contralateral without noise	Right	14,4	12,9	9,3	10,8	2
13	A	Contralateral with noise	Right	13,7	12,9	8,9	10,6	1,7
13	A	Efferent Suppression	Right	0,7	0	0,4	0,2	0,3
14	B	Ipsilateral	Left	15,6	18,9	12,9	-1	-7,3
14	B	Contralateral without noise	Left	19,5	20,1	13,2	0,7	-4,2
14	B	Contralateral with noise	Left	19,3	20,2	12,9	1,1	-4,3
14	B	Efferent Suppression	Left	0,2	-0,1	0,3	-0,4	0,1
14	A	Ipsilateral	Right	7,7	13,6	17,2	7,4	-5,9
14	A	Contralateral without noise	Right	7,8	13,2	19	8,2	-2,1
14	A	Contralateral with noise	Right	8,1	12,8	18,8	8,1	-1,6
14	A	Efferent Suppression	Right	-0,3	0,4	0,2	0,1	-0,5
15	B	Ipsilateral	Left	15,2	11,7	10,3	2,9	-0,4
15	B	Contralateral without noise	Left	16,4	11	10,4	3,3	0,8
15	B	Contralateral with noise	Left	16	10,8	10,2	3	0,9
15	B	Efferent Suppression	Left	0,4	0,2	0,2	0,3	-0,1
15	B	Ipsilateral	Right	6,6	12,3	11,1	5	3
15	B	Contralateral without noise	Right	8,8	13	15,2	5	3,5
15	B	Contralateral with noise	Right	7,4	12	15,3	4,4	4
16	B	Ipsilateral	Left	-5,7	-11,6	-16	-12,4	-9,5
16	B	Contralateral without noise	Left	0,8	-5,7	-14,6	-18,8	-4,8
16	B	Contralateral with noise	Left	0,6	-5,4	-15	-15,8	-5,1
15	B	Efferent Suppression	Right	1,4	1	-0,1	0,6	-0,5
16	B	Ipsilateral	Right	-2,1	5,8	-3,1	-11,3	-9,4
16	B	Contralateral without noise	Right	5,8	10,9	1,6	-7,9	-9,5
16	B	Contralateral with noise	Right	5,4	10,9	1,5	-7,1	-9,2
16	B	Efferent Suppression	Right	0,4	0	0,1	-0,8	-0,3
17	B	Ipsilateral	Left	5,4	0,6	-3,7	-8,6	-8,1
17	B	Contralateral without noise	Left	7,8	2,8	-0,6	-8	-5
17	B	Contralateral with noise	Left	7,8	2	0,3	-6,8	-4,4
17	B	Ipsilateral	Right	2,2	2,5	3,7	-7,6	-6,5
17	B	Contralateral without noise	Right	3,8	4,5	6,1	-4,8	-5,4
17	B	Contralateral with noise	Right	2,7	4,1	5,7	-5,2	-7
17	B	Efferent Suppression	Right	1,1	0,4	0,4	0,4	1,6
18	B	Ipsilateral	Left	8,5	6,3	1,8	-1,4	-1,1
18	B	Contralateral without noise	Left	11,1	14	4,5	-2,7	-1,5

18	B	Contralateral with noise	Left	10,6	13,9	4,3	-2,7	-1,2
18	B	Efferent Suppression	Left	0,5	0,1	0,2	0	-0,3
18	B	Ipsilateral	Right	8,1	6,7	1,9	-7,4	-6,6
18	B	Contralateral without noise	Right	14,4	16,8	4,3	0	-0,1
18	B	Contralateral with noise	Right	14,3	16,7	3,9	0	-0,7
18	B	Efferent Suppression	Right	0,1	0,1	0,4	0	0,6
19	B	Ipsilateral	Left	3,2	12,4	3,1	-6,8	-5
19	B	Contralateral without noise	Left	9	14,9	6,2	-5,5	-3,4
19	B	Contralateral with noise	Left	8,5	14,4	5,5	-6,2	-3,5
19	B	Ipsilateral	Right	12,5	12,3	9,9	-0,8	-5,6
19	B	Contralateral without noise	Right	15,6	16,3	10,5	-1,1	-3,6
19	B	Contralateral with noise	Right	14,8	16,3	10,4	-0,8	-2,8
19	B	Efferent Suppression	Right	0,8	0	0,1	-0,3	-0,8
20	A	Ipsilateral	Left	7,8	4,6	2,2	-1	-4,6
20	A	Contralateral without noise	Left	12,3	9,9	4,4	1,6	-2
20	A	Contralateral with noise	Left	11,8	9,8	4,5	1,4	-1,8
20	A	Efferent Suppression	Left	0,5	0,1	-0,1	0,2	-0,2
20	A	Ipsilateral	Right	5,3	6,4	2,1	-2,3	-2,2
20	A	Contralateral without noise	Right	6	6,6	1,2	1,1	-2,4
20	A	Contralateral with noise	Right	6,2	6,4	0,9	0,7	-2,2
21	A	Ipsilateral	Left	5,1	11,5	3,3	3,4	6,7
21	A	Contralateral without noise	Left	6,9	12,3	4,1	4,5	6,5
21	A	Contralateral with noise	Left	6,2	11,7	3,6	3,7	6,1
21	A	Efferent Suppression	Left	0,7	0,6	0,5	0,8	0,4
21	A	Ipsilateral	Right	9,5	10,9	0,4	-2,9	-4,8
21	A	Contralateral without noise	Right	9,8	13,7	3,9	-2	-4,9
21	A	Contralateral with noise	Right	9,6	13,6	3,7	-1,8	-4,8
21	A	Efferent Suppression	Right	0,2	0,1	0,2	-0,2	-0,1
22	A	Ipsilateral	Left	6,8	6,3	7,4	10,5	0,2
22	A	Contralateral without noise	Left	10,4	8,1	11,2	12,6	0,4
22	A	Contralateral with noise	Left	9,6	8,8	10,6	12,6	0,2
22	A	Efferent Suppression	Left	0,8	-0,7	0,6	0	0,2
22	A	Ipsilateral	Right	7,8	2,1	-2,5	1,6	0
22	A	Contralateral without noise	Right	9,3	3,7	1,6	4,1	0,7
22	A	Contralateral with noise	Right	8,6	3	1,5	4,1	0,4
22	A	Efferent Suppression	Right	0,7	0,7	0,1	0	0,3
23	B	Ipsilateral	Left	6,5	14,5	3,2	-4,3	-7,5
23	B	Contralateral without noise	Left	14	16,6	6,6	3,2	-5,6
23	B	Contralateral with noise	Left	13,7	16,1	6,6	3	-6
23	B	Efferent Suppression	Left	0,3	0,5	0	0,2	0,4
23	B	Ipsilateral	Right	11,4	9,7	5,1	-3,3	-4,9
23	B	Contralateral without noise	Right	15	11,2	9,1	-0,3	-0,6
23	B	Contralateral with noise	Right	14,7	11,2	8,9	-0,6	-0,8
23	B	Efferent Suppression	Right	0,3	0	0,2	0,3	0,2

24	A	Ipsilateral	Left	4,5	9	8,4	2,6	2,6
24	A	Contralateral without noise	Left	9,9	11,7	10,2	5	4,4
24	A	Contralateral with noise	Left	9,9	11,5	9,8	5,1	4,7
24	A	Efferent Suppression	Left	0	0,2	0,4	-0,1	-0,3
24	A	Ipsilateral	Right	8,9	12,2	6,3	4	1,3
24	A	Contralateral without noise	Right	10	11,3	7,2	3,8	1,5
24	A	Contralateral with noise	Right	9,6	11	7	3,6	1,7
24	A	Efferent Suppression	Right	0,4	0,3	0,2	0,2	-0,2
25	A	Ipsilateral	Left	13,7	15	11,3	-1,6	-10,4
25	A	Contralateral without noise	Left	14,5	16,1	12,9	-0,8	-7,7
25	A	Contralateral with noise	Left	14,9	16	12,5	-0,9	-7
25	A	Efferent Suppression	Left	-0,4	0,1	0,4	0,1	-0,7
25	A	Ipsilateral	Right	11,5	11,7	5,9	-0,5	-9,2
25	A	Contralateral without noise	Right	12,7	13,3	7,9	-0,3	-5,3
25	A	Contralateral with noise	Right	12,4	13,1	7,8	-0,5	-5,4
25	A	Efferent Suppression	Right	0,3	0,2	0,1	0,2	0,1
26	A	Ipsilateral	Left	-3,8	-5,1	-5,5	1,1	-0,6
26	A	Contralateral without noise	Left	2,1	8	7,7	3,9	0,6
26	A	Contralateral with noise	Left	2,7	8	7,6	3,2	0,3
26	A	Efferent Suppression	Left	-0,6	0	0,1	0,7	0,3
26	A	Ipsilateral	Right	2,6	2,7	0,9	0	0,4
26	A	Contralateral without noise	Right	8,8	7,9	5,7	2,4	1,8
26	A	Contralateral with noise	Right	8,8	7,4	5,4	2	1,9
26	A	Efferent Suppression	Right	0	0,5	0,3	0,4	-0,1
27	A	Ipsilateral	Left	7,8	7,5	-3,4	-4,3	-4,9
27	A	Contralateral without noise	Left	13,8	8,8	-3,5	-1,8	-1,9
27	A	Contralateral with noise	Left	13,4	7,8	-3,7	-1,9	-2,5
27	A	Efferent Suppression	Left	0,4	1	0,2	0,1	0,6
27	A	Ipsilateral	Right	12,9	11,1	3,8	-1,6	-6,4
27	A	Contralateral without noise	Right	15,6	10,2	2,9	-2,2	-6,9
27	A	Contralateral with noise	Right	15,2	9,3	1,7	-2,4	-6
27	A	Efferent Suppression	Right	0,4	0,9	1,2	0,2	-0,9
28	B	Ipsilateral	Left	6,1	13,3	6,7	3,5	-4,8
28	B	Contralateral without noise	Left	13,2	16,2	13,6	6,5	-7,3
28	B	Contralateral with noise	Left	12,9	15,9	13,6	5,9	-7,6
28	B	Efferent Suppression	Left	0,3	0,3	0	0,6	0,3
28	B	Ipsilateral	Right	13,5	11,9	13	9	-3
28	B	Contralateral without noise	Right	17	17,1	16	10,8	-3,7
28	B	Contralateral with noise	Right	16,6	17,1	15,7	10,8	-2,9
28	B	Efferent Suppression	Right	0,4	0	0,3	0	-0,8
29	B	Ipsilateral	Left	-9,4	-10,4	-11,3	-11,9	-11,1
29	B	Contralateral without noise	Left	-0,4	9,2	7,6	-1,1	0,7
29	B	Contralateral with noise	Left	-0,2	9,2	7,5	-1,3	0,5
29	B	Ipsilateral	Right	-3,3	-7,8	-5,6	-7,9	-7,6

29	B	Contralateral without noise	Right	4,2	9,4	-2,9	-13,4	1,9
29	B	Contralateral with noise	Right	4	9,5	-3,1	-14,4	1,7
30	B	Ipsilateral	Left	0,9	3,3	-0,2	4,3	-0,4
30	B	Contralateral without noise	Left	6	6,3	1,3	5,8	0,7
30	B	Contralateral with noise	Left	6,2	6,1	1	5,7	0,2
30	B	Efferent Suppression	Left	-0,2	0,2	0,3	0,1	0,5
30	B	Ipsilateral	Right	10,5	8,6	-1,1	6,5	1,6
30	B	Contralateral without noise	Right	15	11,3	1,3	7,7	2,9
30	B	Contralateral with noise	Right	14,8	11	1,5	7,7	3,1
30	B	Efferent Suppression	Right	0,2	0,3	-0,2	0	-0,2
31	A	Ipsilateral	Left	10,5	10,6	8,9	-0,6	-5,5
31	A	Contralateral without noise	Left	13,1	11,3	10,1	-1,3	-5,4
31	A	Contralateral with noise	Left	12,5	10,9	9,6	-1,5	-5,2
31	A	Efferent Suppression	Left	0,6	0,4	0,5	0,2	-0,2
31	A	Ipsilateral	Right	11	18	10,2	5,6	-0,5
31	A	Contralateral without noise	Right	14,2	23	11,1	5,3	0,4
31	A	Contralateral with noise	Right	14	22,8	10,5	4,9	-0,6
31	A	Efferent Suppression	Right	0,2	0,2	0,6	0,4	1
32	B	Ipsilateral	Left	5,1	-1,2	1,2	-11	-12,8
32	B	Contralateral without noise	Left	6,7	4,3	6,2	-5,1	-12,3
32	B	Contralateral with noise	Left	6,4	3,9	6	-5,4	-15,3
32	B	Efferent Suppression	Left	0,3	0,4	0,2	0,3	3
32	B	Ipsilateral	Right	-1,2	4,9	7,6	-8	-6,7
32	B	Contralateral without noise	Right	9,4	14,8	11,7	-1	-14,3
32	B	Contralateral with noise	Right	10,3	14,7	11,8	-1,9	-13,2
33	A	Ipsilateral	Left	5,7	12,2	3,6	0,6	-3,9
33	A	Contralateral without noise	Left	13,9	16,5	4,4	1,6	-1,4
33	A	Contralateral with noise	Left	14,4	16,2	4,6	1,7	-1,2
33	A	Efferent Suppression	Left	-0,5	0,3	-0,2	-0,1	-0,2
33	A	Ipsilateral	Right	2,6	0,9	6,9	1	-0,5
33	A	Contralateral without noise	Right	-2,4	12	8,2	2	0,3
33	A	Contralateral with noise	Right	-1,5	13,2	7,4	2,2	-1,3
34	B	Ipsilateral	Left	4,5	7,9	1,4	0,7	-1,5
34	B	Contralateral without noise	Left	8,6	9	3,9	3,9	-2,4
34	B	Contralateral with noise	Left	8,2	8,9	3,6	3,6	-1,9
34	B	Efferent Suppression	Left	0,4	0,1	0,3	0,3	-0,5
34	A	Ipsilateral	Right	7,8	11	5,1	4,5	-9,3
34	A	Contralateral without noise	Right	13,1	15,3	8,8	5,3	-6,6
34	A	Contralateral with noise	Right	12,3	14,9	8,7	5,3	-9,1
34	A	Efferent Suppression	Right	0,8	0,4	0,1	0	2,5
35	B	Ipsilateral	Left	3,4	-5	-12,9	-6,7	-11,2
35	B	Contralateral without noise	Left	5,7	0,7	-4,6	-1,7	-13,1
35	B	Contralateral with noise	Left	5,7	0,1	-5,4	-1,5	-14,7
35	A	Ipsilateral	Right	5,6	-1,4	-12,9	-9,9	-10,6

35	A	Contralateral without noise	Right	8,1	-1,8	-2,2	-9,7	-11
35	A	Contralateral with noise	Right	7,6	-2,9	-1,5	-10,4	-11,2
36	B	Ipsilateral	Left	3,9	13,7	8,5	11,2	8,9
36	B	Contralateral without noise	Left	3,7	18,4	19,5	12	8,7
36	B	Contralateral with noise	Left	4,2	18,5	19	12	8,7
36	B	Efferent Suppression	Left	-0,5	-0,1	0,5	0	0
36	A	Ipsilateral	Right	14,7	9,7	12,9	15,2	17,7
36	A	Contralateral without noise	Right	15,7	13,8	12,9	15,6	17,8
36	A	Contralateral with noise	Right	15,5	13,7	12,4	15,5	17,9
36	A	Efferent Suppression	Right	0,2	0,1	0,5	0,1	-0,1
37	A	Ipsilateral	Left	8,7	13,5	8,8	4,8	1,3
37	A	Contralateral without noise	Left	17	15,5	10,1	6,7	7,1
37	A	Contralateral with noise	Left	17,2	15,4	9,8	6,8	7,3
37	A	Efferent Suppression	Left	-0,2	0,1	0,3	-0,1	-0,2
37	A	Ipsilateral	Right	11,6	15,4	13,8	1	2,4
37	A	Contralateral without noise	Right	14,6	17,1	15	2,7	4,6
37	A	Contralateral with noise	Right	14,4	17,1	15	2,4	4,8
37	A	Efferent Suppression	Right	0,2	0	0	0,3	-0,2
38	B	Ipsilateral	Left	3,1	4,1	4,8	-1,2	-4,8
38	B	Contralateral without noise	Left	7,1	5,4	7,8	0,4	-1
38	B	Contralateral with noise	Left	8,4	4,3	8,2	0,7	-1,3
38	A	Ipsilateral	Right	0,4	0,4	9,8	3,7	-2,4
38	A	Contralateral without noise	Right	-5,5	8,2	15,3	5,3	0,1
38	A	Contralateral with noise	Right	-0,4	9,1	14,9	5	-0,2
39	A	Ipsilateral	Left	2,2	8,8	8	2,9	5,9
39	A	Contralateral without noise	Left	6,4	9,3	9,1	4,4	6,6
39	A	Contralateral with noise	Left	5,7	9,1	9,1	4,6	6,9
39	A	Efferent Suppression	Left	0,7	0,2	0	-0,2	-0,3
39	A	Ipsilateral	Right	6,7	11,2	6,2	2,8	4,2
39	A	Contralateral without noise	Right	5	15,5	10,4	4,1	4,7
39	A	Contralateral with noise	Right	4,7	15,4	10,7	4,2	4,3
39	A	Efferent Suppression	Right	0,3	0,1	-0,3	-0,1	0,4
40	A	Ipsilateral	Left	8,2	15,9	3,6	12,3	12,7
40	A	Contralateral without noise	Left	8,7	13,3	5,2	11,7	12,6
40	A	Contralateral with noise	Left	7,1	13,3	5	11,6	12,5
40	A	Efferent Suppression	Left	1,6	0	0,2	0,1	0,1
40	A	Ipsilateral	Right	6,4	4,7	11,1	12	11,8
40	A	Contralateral without noise	Right	1,1	1,7	9,6	12,3	11,1
40	A	Contralateral with noise	Right	-0,6	2,2	9	12,2	11,2
40	A	Efferent Suppression	Right	1,7	-0,5	0,6	0,1	-0,1
41	A	Ipsilateral	Left	5,2	7,1	1	1,5	-1,2
41	A	Contralateral without noise	Left	6,8	11	3,8	3,6	-2
41	A	Contralateral with noise	Left	6,7	10,9	3,7	2,8	-2
41	A	Ipsilateral	Right	-0,3	2,4	-6,5	7,5	2,3

41	A	Contralateral without noise	Right	2,6	1,4	-2	10,8	5,5
41	A	Contralateral with noise	Right	2,3	1,3	-2,7	10,8	5,6
41	A	Efferent Suppression	Right	0,3	0,1	0,7	0	-0,1