Validation of the LittlEARS® Questionnaire and the Adaptive Auditory Speech Test (AAST) in normal-hearing Maltese-speaking children

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Dedication

I dedicate this dissertation to Mark and to our son Luke.

Declaration

I hereby declare that this work is original.

Acknowledgements

I would like to express my gratitude towards all the people who contributed to the completion of this research study.

Special thanks goes to Prof. Dr. Frans Coninx for his support and guidance in these past years. Thank you for inspiring me to embark on this journey. Although we did not manage to end this project together, I am forever grateful for your motivation and encouragement in moments of struggle.

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A special thanks to my beloved friend Myriam, for proofreading it and making sure my message gets across.

Last but not least, a heartfelt thanks goes to my partner Mark for always believing in me and for supporting me throughout every phase of this incredible journey.

Foreword

Diese Dissertation wurde von der Humanwissenschaftlichen Fakultät der Universität zu Köln im Juli 2021 angenommen.

Abstract

Despite the widespread screening of hearing loss at birth, some children with permanent hearing loss still go undetected, and delayed onset hearing loss remains a concern. Screening post Universal Newborn Hearing Screening (UNHS) is attracting increased interest across researchers and clinicians alike.

This study aimed to develop tools that evaluate auditory development and speech recognition skills of Maltese speaking children. A translated version of the LittlEARS® questionnaire was used to examine auditory development in 398 young children less than 2 years of age. Analysis aimed at generating normative data from the total scores of the participants and their age in months. A Maltese version of the Adaptive Auditory Speech Test (AAST) was used to examine the speech recognition skills of 208 children and 40 adults in Quiet, Noise and High Frequency. The aims were to determine the norms in these 3 settings, in adults and children aged 4 years and older.

This study confirmed that the Maltese version of LittlEARS® is a valid and reliable tool to evaluate auditory development in children less than two years of age. Norm curves were comparable to the original German data. The Maltese version of AAST confirms an age dependent norm threshold with a significant improvement in threshold being observed as children grow older, similar to other AAST versions. This was evident across the 3 test settings. An approximate difference of 10dB was also noted between 4-year-old and 10-year-old children in AAST in Quiet. Thresholds of 10-year-olds and adults were similar in both the Quiet and High frequency versions. Implications for post UNHS using these tools are addressed.

Contents

List of Abbreviations

AAST	Adaptive Auditory Speech Test
EARS	Evaluation of Auditory Responses to Speech
F0	Fundamental frequency
IfAP	Institute for Audio Pedagogics
LEAQ	LittlEARS® Auditory Questionnaire
OAEs	OtoAcoustic Emissions
PI	Performance intensity
PTA	Pure Tone Average
SIN	Speech in Noise
SNR	Signal-to-noise ratio
SRT	Speech recognition threshold
UNHS	Universal Newborn Hearing Screening
WHO	World Health Organisation

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1. INTRODUCTION

Universal Newborn Hearing Screening (UNHS) programmes enable the detection of hearing loss in newborns in the first few days of life. Their implementation continues to grow around the world, and over the past 20 years has become the standard of care in many countries (Wroblewska-Seniuk et al., 2017). In Malta, it was officially launched in 2021 after various attempts to initiate the screening over the last couple of years. Despite the expected nationwide use of screening in Malta, some children with hearing loss will still go undetected. This is due to progressive, late onset or acquired hearing loss, false positives, and screening device failures (Watkin & Baldwin, 2011).

The aim of UNHS, ultimately, is to lower the age at the time of diagnosis to enable early intervention and management (Wroblewska-Seniuk et al., 2017). This is why it is very important to continue evaluating children's auditory development during infancy in addition to the early newborn screening. Schaefer et al., (2019) reported the use of the LittlEARS® (LEAQ) questionnaire as a suitable tool for identifying abnormal or delayed hearing development in 1 year old German infants. LEAQ is a valid, language-independent tool for assessing the early auditory behaviour of infants and toddlers. It was originally developed in German (Weichbold et al., 2005) and has been translated into several other languages. In Malta, there is also the need for a quick and easy method for assessing early auditory development in the Maltese language.

This research project aims to tackle this clinical necessity for the Maltese Islands as language-specific speech assessments in Maltese are very limited. This is also true in the case of speech audiometry. Whilst speech audiometry materials have become an essential part in the evaluation of hearing loss across the world, a standard audiological assessment in the Maltese Islands lacks the use of normed speech tests on the Maltese population. The Maltese version of the Automatic Adaptive Speech Test (AAST) will be constructed to meet this aim. AAST was developed by Professor Frans Coninx in 2005 in order to easily, quickly and reliably record the Speech Recognition Threshold (SRT) in children in Quiet or with background noise. Even though it was designed especially for young children starting from 3-4 years old, it can be used just as well to test adults. Using a closed set of only 6 stimulus words, AAST is minimally dependent on an individual's vocabulary. Speech material for AAST is available in several languages, and its applications also include establishing a baseline prior to amplification or rehabilitation and outcome measures for hearing aids and cochlear implants.

1.1 Outline of the dissertation

This dissertation consists of 6 chapters. The introduction aims to give a brief introduction to the topic under study. The following chapter, Chapter 2, will give an overview on the literature available in relation to screening post-UNHS and the use of the LEAQ. The development of speech perception skills in children and the tools for assessment are also discussed in the context of speech audiometry tests such as AAST. Basic information on the Maltese language is also included. The aims and objectives of this research are outlined at the end of the chapter. Chapter 3 will focus on the development of the tools used in this study. The translation process of the Maltese version of LEAQ is described in detail as well as the development of the Maltese words chosen for the AAST. The procedure used for recording of the speech material and data collection is also outlined. The results obtained in this study are presented in Chapter 4. These are discussed more in detail in Chapter 5 in relation to the aims and research questions of this research. Conclusions drawn from this study, along with other future recommendations for the Maltese versions of LEAQ and AAST, are explored in Chapter 6.

2. LITERATURE REVIEW

2.1 Development of auditory skills

Auditory skills in infancy are necessary for the child's communicative progress and have a fundamental role in the child's further speech and language development. Northern and Downs (1991) classified auditory behavioural responses in infants as reflexive, orienting or attentive. Werner (2007) described auditory development in children as consisting of 3 stages. The first stage lasts up to the first 6 months of age and involves the maturation of the middle ear and the brainstem auditory pathways. In the second stage, the ability to focus on one aspect of the speech signal emerges. This stage continues up to 5 years of age. In the second and third stage, the auditory cortex and central processing develop further. The third and last stage of auditory development involves the ability to make use of different sound features in a flexible manner under changing listening conditions (Werner, 2007).

The implementation of newborn screening and subsequent earlier identification and intervention has necessitated more tools for the assessment of younger infants and children (May-Mederake et al., 2010). Therapy goals for rehabilitation and parent counselling lie on the knowledge of how the child is performing in comparison with normal hearing peers. Evidence-based practice thus relies on having validated measures of auditory skill development. Over the years, several tools have been developed to assess progress in children with a hearing loss, but most were inadequate for the very young ones. Parental questionnaires proved to be a useful tool in the evaluation of young children (Meinzen-Derr et al., 2007; Spitzer & Zavala, 2011; Thal et al., 2007). Early preverbal auditory behaviour is not always observed in a clinical setting. Some children are uncooperative in unfamiliar surroundings, whilst others are too young to take standardised speech tests. Through questionnaires, parents are able to describe quickly and concisely their child's auditory behaviours and responses in various situations. The assessed behaviours cover the stages of detection, discrimination, identification and understanding at different levels of development. These subjective measures, based on observations in real-life settings, have been suggested to complement the objective measures, as well as being applicable to children with complex needs (Coninx et al. 2009).

The availability of tools with normative data in several languages is essential for documenting the benefit of rehabilitation in infants and children with hearing aids and cochlear implants. In the review of Bagatto et al. (2011) and Gan et al. (2018), the MEDEL LittlEARS® Auditory Questionnaire (Weichbold et al., 2005) was rated as one of the most promising instruments, with the highest rating in terms of most characteristics. It was designed as an extension of the Evaluation of Auditory Responses to Speech (EARS) by Allum-Mecklenburg (1996) which assessed the progress of implanted children 3 years and older. Consequently, the LEAQ assesses the auditory development and progress of children with hearing aids and cochlear implants less than 2 years of age (May-Mederake et al., 2010). It can also gauge the auditory development of normal hearing infants up to 2 years of age (Weichbold et al., 2005). The LEAQ takes less than 10 minutes to complete. It consists of 35 dichotomous "yes/no" questions which are drawn from speech-language research on the receptive, semantic, and expressive vocal behaviours and developmental auditory behaviour milestones of infants and young children. The items are arranged developmentally based on the work of Northern and Downs (1991). Initial questions reflect attending behaviour, such as Question 1, "Does your child respond to a familiar voice?" Question 13 is an example of orienting behaviour "Does your child look for sound sources above or below?" Semantically related behaviours are represented in questions such as "Does your child know that a certain sound is related to a certain object or event" (Question 17) and "Does your child obey complex commands" (Question 34)?

Most of the items also include an example of the behaviour being assessed in the question, thereby increasing the objectiveness of the tool, for example Question 7, "Does your child respond to distant sounds? (When being called from another room). The instructions also inform the parents to tick 'Yes' if they have observed the behaviour at least once, and 'No' if they have never observed such behaviour. The questionnaire should be stopped once they respond negatively to 6 consecutive questions. The total score is the sum of questions answered 'Yes". The total score is then compared to the expected value and minimal value. The former is the average score achieved by a normal hearing peer, whilst the latter is the minimum score a normal hearing child at that age should attain on the LEAQ. If a child scores above the minimum value, there is a high probability (95%) that their auditory development is age appropriate. On the contrary, if the minimum score is lower, the child should be assessed further (Weichbold et al., 2005).

Since its development in 2005, LEAQ has been validated in normal hearing German-speaking children and translated into more than 20 languages, all of which have confirmed that LEAQ is a valid and reliable tool in assessing the auditory behaviour of children under 2 years of age (Bagatto, Brown, et al., 2011; Coninx et al., 2009; Geal-Dor et al., 2011; Wang et al., 2013). It is therefore considered as an age and language independent tool that can be used internationally to assess auditory behaviour in normal hearing children and monitor progress in aided children less than 2 years of age.

2.2 Importance of screening beyond UNHS

Implementation of Universal Newborn Hearing Screening (UNHS) programmes worldwide has enabled the early identification of hearing loss in the newborn (Lü et al., 2011; Wroblewska-Seniuk et al., 2017). This has meant a significant reduction in the average age of permanent childhood hearing loss identification from 24–30 months to 2–3 months (Harrison et al., 2003; Lü et al., 2011). Nevertheless, this success does not diminish the need of screening older children since it is widely known that not all cases of hearing loss in early childhood are detected in the newborn period (Watkin & Baldwin, 2011).

Hearing loss may be progressive, late onset or acquired through known causes such as infection, ototoxicity, and chemotherapy. Lack of identification at birth may also be due to false negatives, parental refusal to screen, lost to follow-up due to a lack of a comprehensive screening programme (Fortnum, 2003; Hall, 2016). A surprisingly high proportion of children identified with hearing loss at preschool age would have passed UNHS. In his study, Fortnum noted that up to half of the children identified with hearing loss at 9 years of age passed UNHS (Fortnum et al., 2001). Prevalence of hearing loss in school age children is at least double than in newborns. Muñoz et al. (2014) and Bamford et al. (2007) noted the increased prevalence of hearing loss in school-age children (6 to 10 per 1000) rather than for infants (2-3 per 1000). Whilst mild hearing loss is more likely to be missed (Johnson et al., 2005), Young et al. (2011) also found that approximately 30% of paediatric implant recipients passed UNHS, irrespective of the cause of hearing loss or the presence or absence of known risk factors.

Ongoing screening for hearing loss beyond newborn screening and throughout childhood is therefore imperative in order to assist in the identification of hearing loss that is late-onset, acquired, or not detected in newborn. Secondly, it is important to screen children of all ages due to the consequences of untreated hearing loss. When left undetected, hearing loss can adversely affect speech and language development, literacy skills and academic achievement (Korver et al., 2010; Nikolopoulos, 2015). In addition, it may also affect their social interaction, well-being and quality of life (Roland et al., 2016). Therefore, this under identification is potentially of significant concern to audiologists, early interventionists, speech-language pathologists, parents, and educators.

Besides the clinical effects of unidentified hearing loss in children, the economic burden is significant. The World Health Organization (WHO) (WHO, 2017) estimates that the global cost of unidentified hearing loss is approximately 800 billion international dollars yearly (McCreery & Stelmachowicz, 2013; WHO, 2017). One of the earlier challenges was to identify a point in time when these children could be screened. Many researchers and medical professionals recommend the introduction of a screening programme between UNHS and school age (Holzinger et al., 2016). In a 2006 position statement (APA, 2006), the American Academy of Paediatrics had suggested the screening be administered at a child's 30 month visit. However, objective hearing devices such as Otoacoustic Emissions (OAEs) were not available at paediatricians' offices and behavioural screening was not feasible (Ross et al., 2008). One possible solution for an additional universal hearing screening is during school entry. School entry hearing screening helps address the gap occurring after the newborn period and enables access to the children population (WHO, 2017). Nonetheless, the adoption of school hearing screening programmes across and within countries is inconsistent (Krueger & Ferguson, 2002; AAA, 2011; Sekhar et al., 2011; Swanepoel et al., 2013). Cost effectiveness of school hearing screening programmes is inconsistent amongst studies. In their systematic review, Yong et al. (2020) noted that Fortnum et al., (2016) were the only authors to find that school hearing screening was not cost-effective as compared with no screening. Schaefer et al., (2019) reported the use of the LEAQ screening as a suitable tool for identifying abnormal or delayed hearing development in 1 year old German infants. The authors state that it may also help in identifying a late-onset or progressive hearing loss that developed between NHS and 1 year of age. In Malta, developmental assessment for babies is carried out at 3 routine visits at 6 weeks, 8 months, and 18 months respectively. These visits are done at the Well-Baby Clinics which are available at community level. At these visits, clinical examinations are carried out to evaluate whether the child has reached certain developmental milestones. Including a hearing screen at one of these stages would potentially aid in identifying children with hearing loss who were not identified at birth.

Screening methods should be effective in identifying children with hearing loss; that is, they need to have both high sensitivity and specificity. The methods employed to conduct the screen can be classified into two groups: subjective and objective measures. Subjective measures, such as questionnaires, have been proven to have low sensitivity and specificity (McPherson et al., 2010). On the other hand, pure tone audiometry (PTA), standard, automatic or online, continues to be the gold standard for screening children (Yong et al., 2020). Objective methods, such as OAEs, are on the increase due to their rapid test time and lack of behavioural response needed from the child. Sideris and Glattke (2006), reported no significant differences in the referral rates of pure tone and Transient OAE screening. Referral rate also tends to decrease significantly with increasing age (Wu et al., 2014). The challenges that affect the success of a screening programme also include the physical characteristics of the school, equipment malfunction and administrative constraints such as shortage of staff, personnel competency and tracking of children (Allen et al., 2004).

The goal of efficiently identifying children with a hearing loss is overall not met due to the high referral rates and hence low identification of hearing loss (Allen et al., 2004; McPherson et al., 2010). More research is needed in this area.

2.3 Speech development in children

Access to relevant acoustic and linguistic information early in life is essential for the acquisition of speech perception (Kuhl, 2000). Often, this occurs in complex environments where the target speech occurs with competing sounds (Barker & Newman, 2004). The ability to perceive speech in noise in typically developing children is known to reach maturity in early childhood (Ching et al., 2011; Garadat & Litovsky, 2007). Literature shows that compared to adults, children perform poorly on complex listening tasks in challenging listening conditions (Litovsky, 2005; Schafer et al., 2012). They may be especially challenged to understand speech-in-noise due to factors that impede overall auditory perception, such as internal noise and attention (Buss et al., 2006, 2009; Jones et al., 2015; Moore et al., 2010). In addition, they find it more difficult to perceive speech in the context of other speakers (Corbin et al., 2016; Hall et al., 2002). It is believed that the immature ability to separate speech streams and selectively attend to the target speech limits speech recognition in young children (Werner et al., 2012). In adults, these processes are facilitated by the use of significant acoustic differences between target and masker speech. Differences that adults rely on when separating multiple speakers include spatial location cues, asynchronous onset of sentences, and sound characteristics related to the speaker's gender such as the fundamental frequency (F0) (Andreou et al., 2011; Lee & Humes, 2012; Shamma et al., 2011). In older children and adults, biological processes, such as enhanced neural representation of F0, are considered important for speech perception in noise (Anderson et al., 2010; Song et al., 2011). As children get older, speech perception relies on a number of cognitive and linguistic factors, including selective attention, short-term memory and lexical knowledge (Lewis et al., 2010; Mattys et al., 2012).

2.4 Listening at school

This listening disadvantage in young children is of specific concern in a school setting which contains multiple sources of competing sounds (Ambrose et al., 2014; Sörqvist et al., 2014). These may be relatively repetitive and steady over time and hence more predictable, or they may be more dynamic and thus more unpredictable. For example, a child may be exposed to a combination of sounds in his classroom during a science lesson. These could include his teacher speaking, his classmates speaking and noise coming from traffic outside. During the first stage of auditory processing, the child’s ears receive a combination of acoustic waveforms produced by the three different sources. In the second stage, the basic spectral, temporal, and intensity properties of the teacher' speech are first encoded by the child's peripheral auditory system. This encoding is hindered by the competing speech and noise in the classroom, which creates an overlap on the basilar membrane. Thus, the teacher's message, which is transmitted to the child's central auditory system, is degraded by the so-called phenomenon of 'energetic masking'. In stage 3, higher level (auditory, cognitive, and linguistic) top-down processing facilitates the reconstruction of the teacher's spoken message. Unfortunately, the competing background sounds of other children and traffic may also disrupt this higher-level processing, making it difficult for the child to disentangle the target speech from the competing sounds. This is referred to as 'informational masking'.

Typically, adults possess advanced cognitive and linguistic skills that enhance listening in challenging situations. On the contrary, children are more likely to be impacted by a degraded speech signal. The relationship between audibility and speech understanding in children has been extensively reported. The intelligibility of the competing noise signal correlates with how distracting it is (Mealings et al., 2015). Children necessitate a more favourable SNR to perform as well as adults (Corbin et al., 2016; Elliott, 1979; Hnath-Chisolm et al., 1998; Johnson, 2000; Krizman et al., 2017; McCreery et al., 2010). In a classroom setting, the SNR relates to the difference between the level of background noise and the level at which the teacher is talking. In order for children to understand 95% of the auditory message, an SNR of approximately +15dB is needed (McCreery et al., 2010; Mealings et al., 2015).

In several studies, mature performance has been reported to occur at about 9–10 years of age (Corbin et al., 2016; Nishi et al., 2010). Speech recognition is more difficult when the masker is composed of competing speech by a small number of talkers, rather than steady state noise (Brungart et al., 2001; Carhart et al., 1969; Freyman et al., 2004). A study by Hall

(2002) reports higher SNR thresholds of about 7dB in 5-10-year-old children when compared to adults. In contrast, only a 3dB higher SNR was required in speech-shaped noise. Later studies also confirmed this gap (Bonino et al., 2013; Leibold & Buss, 2013; Wightman et al., 2003).

These findings have significant implications for children in school settings since classrooms tend to be a source of competing sounds. Accessing the phonological structure of speech is also important for their literacy development (Nittrouer, 2002). However, the evidence for a relationship between phonological awareness skills and speech perception in noise is still unclear (Lewis et al., 2010). In addition, the level of noise in a classroom has been documented by several authors to be high enough to interfere with speech perception (Bradley & Sato, 2008; Shield & Dockrell, 2004). Room acoustics, such as reverberation, can also hinder speech understanding, limiting the amount of acoustic information accessible to young children (Neuman et al., 2010).

Most importantly, children's limited speech recognition skills can be further reduced by hearing loss. Impaired speech discrimination secondary to hearing loss necessitates increased listening effort and impairs identification of speakers and acoustic location (Ching et al., 2018). Hence, it is necessary to gain knowledge on the speech recognition skills of normal hearing children in order to quantify the impact of hearing loss on these children. Therefore, hearing assessment outcomes also need to include testing in noise to capture the difficulties encountered by children in challenging listening conditions.

2.5 Speech Audiometry

Over the years, speech audiometry has been increasingly utilised alongside pure tone audiometry to clinically quantify a person's ability to hear speech. It evaluates the person's ability to hear speech in their daily life, within their family, community, and society.

In clinical practice, it adds validity to the pure tone audiogram and allows for quantitative measures of speech understanding through test materials that closely resemble everyday listening tasks. Speech audiometry adds diagnostic and prognostic value and also supports rehabilitation and treatment decisions in relation to hearing aids and cochlear implants (Eggermont, 2017).

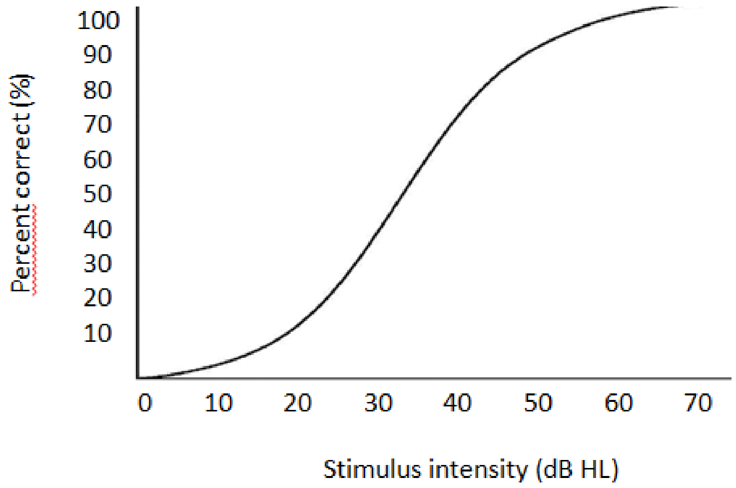
A fundamental component of diagnostic audiology includes the measurement of the hearing threshold for speech. The speech recognition threshold (SRT) test is used most often for this purpose. It is defined as the lowest level at which the individual can correctly recognise 50% of words presented (ASHA, 1988). The selection of test materials for SRT is central for ensuring valid clinical practice. An important consideration is whether the test items are presented in a closed or open set. Whilst closed sets limit the number of responses available, open sets are more difficult as they provide an unlimited number of responses. The choice is dependent on the purpose of the test and the age and skills of the listener (Schoepflin, 2012). The type of stimuli used also varies. In English, bisyllabic words with equal stress on each syllable (spondees) are widely used. However, they are not the only materials available for this purpose. Sentences are also used to obtain SRTs, usually against a background of noise.

Over time, the specific parameters of SRT testing have evolved, and the importance of standardised measures has increased (Di Berardino et al., 2010; Mendel & Owen, 2011). Applicability of standardised tests is indeed only valid on the population on whom they were normed and only in the specific settings used. Across the years, SRT test materials were developed in other languages besides English and the word structures now vary between monosyllables to trisyllables reflecting the linguistic properties of the language. SRT test materials can be found in languages such as German, Arabic, Russian, Swedish, Mandarin, Polish, Vietnamese and Malay to name a few (Ashoor & Prochazka, 1982; Coninx et al., 2009; Lau & So, 1988; Magnusson, 1995; Mukari & Said, 1991; Nguyen, 2017; Nissen et al., 2007; Ozimek et al., 2012). This reflects the idea that the listener should be tested in his native language in order to be familiar to the test items. The words need to be familiar to the listener in order to avoid testing his vocabulary rather than his hearing acuity. Familiarity is one of the 4 essential components for developing SRT tests recommended by Hudgins et al. (1947). The other 3 characteristics are phonetic dissimilarity, a representative sample of speech sounds in the language, and homogeneity of audibility. The latter refers to how easily words are understood when delivered at a constant intensity level. This is commonly plotted as a performance versus intensity function. The performance intensity (PI) function developed by Boothroyd, plots percentage correct scores on the y axis and intensity level of the speech signal on the x axis (Boothroyd, 2008).

The acoustic properties of the speech signal are the initial determinants of this function. As the intensity level of the speech increases, audibility starts to rise above zero. The first components to be heard are the ones with the highest amplitude. As the intensity increases further, lower audibility components are also heard. In order for the signal to be audible to the listener, an increase of 30dB or 40dB above the threshold is needed. The maximum score is traditionally called PB_{max}. Hence, whilst the highest amplitude components determine the threshold of initial audibility, the range over which sound energy is distributed in the amplitude domain determines the range from initial to full audibility (Boothroyd, 2008). Figure 1 shows a typical PI function for words in Quiet. The slope of the graph is a measure of the percentage change in word recognition ability as a function of intensity level of the speech signal. A slope of 2%/dB for instance, would signify a 2% increase in word recognition ability for each increase in intensity of 2dB. The plateau on the other hand, shows that PB_{max} has been reached as the score does not improve any more when the intensity continues to be raised.

Figure 1

Example of the PI function of a normal hearing individual



During the development of a speech audiometry test, one has to ensure that all the words have to be homogeneously audible. In this day and age, digital technology is widely used to make words equally audible, and hence, result in similar SRT results across words. Young et al. determined that the slope of each individual word should be ± 1 SD of the mean to be considered homogenous (Young et al., 1982). Spondee words in English tend to have a steep slope due to their high audibility (Carhart, 1951; Hudgina & Hawkins, 1947; Wilson & Carter, 2001). Research has shown that the SRT materials developed in other languages have slopes of psychometric performance-intensity function on trisyllabic words as steep as the slopes for English spondees (Harris & Christensen, 1996; Harris & Greer, 1997; Harris et al., 2001).

Therefore, homogeneity, both in terms of audibility and slope, is considered an essential factor in development of speech tests as it allows for precision during SRT testing, as well as decreases the length of time needed to determine the SRT. Undeniably, Hudgins and his colleagues' criteria are still the basis of for the development of speech audiometry materials to this day (Boothroyd, 1968; Fu et al., 2011; Harris et al., 2007; Mukari & Said, 1991; Nguyen, 2017; Tillman & Carhart, 1966).

2.5.1 Speech Audiometry in Noise

Speech intelligibility, when measured in Quiet, might not be sensitive to difficulties experienced in the presence of background noise (Andrade et al., 2016; Wilson, 2011). People face challenging listening situations in their daily life. Difficulty in understanding speech-in-noise is a common complaint. The significance of speech-in-noise (SIN) tests was first pointed out by Carhart and Tillman in 1970. Eventually, other authors also corroborated with this notion, and speech-in-noise tests started being developed (Killion & Niquette, 2000; Taylor, 2003; Wilson et al., 2007).

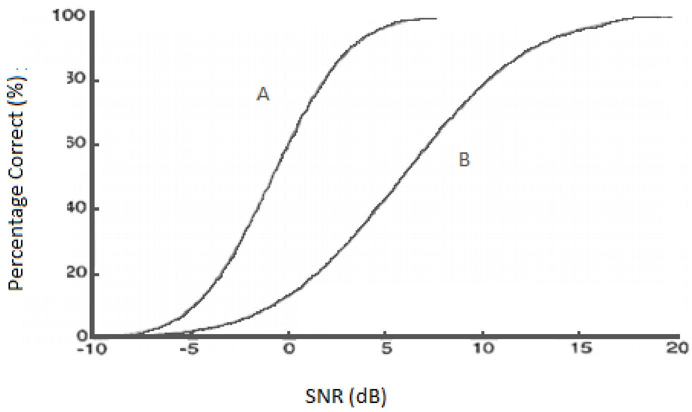
The clinical assessment of speech intelligibility nowadays commonly includes testing in Noise in order to approximate a more realistic environment and to avoid ceiling effects which are more common when testing in Quiet. This is also recommended by professional audiology organisations (BSA, 2019). SIN testing is useful in the selection of amplification devices, determination of patient expectations and as an outcome measure following management of hearing loss (Leclercq et al., 2018; Spyridakou et al., 2020). Through SIN tests, audiologists can quantify the extent of the distortion factor of hearing loss, which is attributed to damage of the inner hair cells or central auditory nervous system. Loss of audibility, on the other hand, is related to damage of the other hair cells and can be restored by additional volume or gain dependent on the audiometric thresholds obtained. The distortion part is not, however, and can only be quantified by testing in noise through signal-to-noise ratio (SNR) loss (Taylor, 2011). Analogous to the term 'hearing loss', which refers to the additional dB (SPL) needed for audibility, SNR loss refers to the dB increase in SNR needed to correctly identify 50% of the words in Noise when compared to normal hearing listeners (Killion,1997). The SNR required by a normal hearing listener is between 0 and

+2dB (Taylor, 2003). An individual with a 5dB SNR loss would therefore need the speech to be 5dB louder than the noise to get 50% speech recognition in Noise.

As Figure 2 demonstrates, the 50% performance level, θ, plotted graphically through the PI function, determines how difficult the test is for the listener. A low θ (Participant A) shows that the test is not difficult for the listener whilst a high θ (Participant B) indicates that a more favourable SNR is needed for 50% word recognition.

Figure 2

Psychometric functions of speech recognition in Noise



SIN tests can be classified as either fixed or adaptive. In the former, the SNR is fixed, as the speech signal is presented at one level and the noise is presented at another level. Examples of fixed tests include the Connected Speech Test (Cox et al., 1987) and the Speech Perception in Noise Test, (Kalikow et al., 1977). In a fixed SNR test, one can simulate all kinds of listening situations, making the test as easy or as difficult as needed. It is also easy to deliver the results of a fixed SNR test to the patient as the result is displayed as percentage correct.

In the latter, testing is done to approximate the SNR needed for 50% speech recognition. In adaptive testing, either the speech or noise level is adaptively changed whilst the other is fixed. For example, the QuickSin (Killion et al., 2004) test fixes the speech level and adaptively changes the noise level. The Hearing in Noise Test (Nilsson et al., 1994), on the other hand, adaptively changes the speech level while keeping the noise level fixed. However, both tests converge to find a SNR value where an SRT of 50% is reached. This will help in identifying the 50% correct point quickly and reliably. It will also avoid ceiling effects, one of the advantages of adaptive SIN tests.

Another factor to be considered is the type of background noise used. Both speech-shaped steady-state noise and babble noise are commonly used to simulate real-world listening situations. Speech-shaped noise is generated by superimposing the speech material on white noise to produce noise with the same long-term spectrum as the speech material itself (Wagener et al, 1999; Wagener et al., 2003). This approach produces noise that masks comprehensively the speech material, yielding steep intelligibility functions needed for accurate SRT determination. On the other hand, multi-talker babble involves several speakers talking simultaneously resulting in none of the conversations being intelligible. The background noise is therefore aperiodic, and speech-spectrum shaped, leading to maximal spectral overlap with the speech. Over the years, researchers have argued over the appropriateness of these maskers. Early on, Carhart and Tillman (1970), contended that steady state maskers such as speech-shaped noise may be inadequate as it will most likely elicit less enhancement of masking than competing speech. Other researchers also argue that multi-talker babble has greater face validity because persons with hearing loss complain of difficulty understanding speech in noise. This is especially so when the noise is composed of multiple talkers, such as in restaurants and other social settings (Wilson, Carnell, et al., 2007). In contrast, Killion et al., (2004), sustain that speech-shaped noise as a continuous noise has the advantage of lessening the variability in noise level, which is present in multi-talker babble. When the amplitude and spectrum of the noise are fluctuating, listeners can take advantage of the temporary gaps in the masker and hence are able to extract more information (Stuart et al., 2010). This type of benefit in modulating noise is referred to as masking release.

2.5.2 Response time and listening effort

There is another aspect to listening beyond task accuracy in speech audiometry. The number of words recognised correctly is a vital measure, but so is the concept of listening effort, as this applies even when speech recognition scores are high. The British Society of Audiology proposed the following definition in a white paper: ''*the mental exertion required to attend to, and understand, an auditory message*'' (McGarrigle et al., 2014, p. 434). The Ease of Language Understanding Model (Rönnberg et al., 2013) postulates that listening to speech is rather effortless in ideal listening conditions. When the quality of the speech signal is degraded either due to noise, hearing loss or complex language, speech recognition may become more effortful. In fact, the relationship between listening effort and task accuracy is limited since a listener may report a task as more effortful even though the score remains the same. A normal hearing person is able to fully understand a message in background noise but will report a greater amount of listening effort when compared to a quiet setting.

In order to measure this cognitive load during listening, accuracy and speed can be measured. This means that accuracy is recorded by percentage of correctly identified words, whilst speed is assessed through response time. Several authors have used the concept of response time as a measure of cognitive load in speech recognition (Meister et al., 2018; Pals et al., 2015; Pisoni et al., 2011; Prodi & Visentin, 2019). Similar findings have been reported across studies. As listening conditions become more degraded, listening effort also increases as evidenced by response time increase.

2.5.3 Speech audiometry in children

A number of different hearing tests may be used to check for hearing loss in children, including visual reinforcement audiometry, play audiometry, pure tone audiometry, tympanometry, OAEs, ABR and speech audiometry. Audiologists are faced with the challenge of choosing the most appropriate hearing test to administer to a given child. PTA, in combination with tympanometry, is the gold standard in children above 4 or 5 years of age in identifying hearing loss and middle ear disorders (Farinetti et al., 2018). Over the years, the importance of incorporating speech audiometry into the test battery has increased (H. Fortnum, 2003; Schoepflin, 2012). Tests focusing on speech understanding provide relevant information about the auditory system and make it possible to predict the development of different skills in children such as language, reading or cognitive abilities (McArdle & Hnath-Chisolm, 2009).

A speech test should be able to provide a measure of the child's ability to perceive phonetic segments, words, and sentences as it may serve as a basis for decisions related to amplification, rehabilitation and in monitoring a child's progress over time. Several variables may affect performance in the paediatric population. Language skills, vocabulary, age, and cognition may potentially impact the results. The test's characteristics may also have an influence. The type of stimulus and response used, type of reinforcement if any, and the memory load can affect a child's performance on a test (Mendel, 2008). Kosky and Boothroyd (2003) recommend that paediatric speech tests meet a number of criteria.

They suggest tests to be:

- Age appropriate in terms of attention, cognition, and fine motor skills
- Motivating
- Independent of vocabulary and higher language skills

- Independent of speech production skills
- Able to assess ability to communicate in daily life

Speech perception test materials must therefore be designed to cater for differing paediatric populations with varying ages and developmental abilities. Developing a speech test that is applicable to all children is difficult due to the vast range of skills these children may have. The aim is for speech recognition to be assessed using valid and reliable clinical tests. Validity, specifically face validity, refers to the extent to which the test measures what it is supposed to measure. It is usually measured as the correlation between the test score and criterion-related variables. Reliability, on the other hand, refers to the consistency of a measure, over time, across items and across different researchers. The relationship between validity and reliability is very important. A test can be reliable but not valid. To be valid, however, a test needs to be reliable. These concepts should guide audiologists in choosing a test which is most fit for the population in mind (Mendel, 2008). In addition to using valid and reliable tools, it is also important to follow the test methodology for accurate assessment and avoid bias (Clark, 2003). Methodological variables that can influence the test result include stimulus familiarity, presentation, and response format, scoring method and masking noise.

Speech recognition at the word level may be measured through open-set tasks or closed-set tasks. The former involves the child to repeat back a stimulus word verbally, forcing the child to retrieve the item from all possible words in his lexical memory. In the latter, the child selects a word from a restricted set of responses (usually pictures), thus limiting the number of comparisons the child needs to carry out. Clopper et al.'s study (2006) confirms that word retrieval plays a larger role in open set tasks. Forced choice picture pointing tasks are thus frequently used to evaluate speech recognition in young children since they do not rely on the child’s speech production skills or accurate scoring of the tester.

2.5.4 Adaptive Auditory Speech Test (AAST)

The adaptive auditory speech test has been developed by Professor Frans Coninx in 2005 in order to easily, quickly and reliably record the Speech Recognition Threshold (SRT) in children in quiet or with background noise. Even though it was designed especially for young children starting from 3-4 years old, it can be used just as well to test adults. Applications for AAST also include the verification of aided thresholds with hearing aids and/ or cochlear implants and screening of Auditory Processing Disorder (AAST in binaural noisy condition).

Using a closed set of only six stimulus words, AAST is minimally dependent on an individual’s lexicon. The test is already established in many countries. Speech material for AAST is available in several languages, including German, English, Dutch, Arabic, Vietnamese, Spanish, Polish, Luxembourgish, Chinese, and Ghanaian. For each language, the same criteria have been followed in the selection of speech material. In German, Dutch, and English, for example, the stimulus words are spondee words (such as airplane, toothbrush, football). When spondee words do not exist in a particular language, for example, Spanish and Arabic, trisyllabic words are used instead. The receptive vocabulary of 3–4-year-old children is also taken into consideration when translating AAST into a different language, along with dialects and other cultural factors. A simple translation is almost always never appropriate. Across different language versions, several phonological properties are also evident. Firstly, the prosodic pattern across the 6 words is the same. Secondly, the variety of the language’s phonemes is represented. The use of spondees and trisyllable words instead of monosyllables enables a larger number of phonemes to be represented in a set of only 6 words. Thirdly, the frequency of occurrence of phonemes is adhered to within groups of phonemes. The group-based phoneme balancing has been part of the development of the AAST versions in different languages (Coninx et al., 2007).

AAST is a closed set testing procedure, where the child sees 6 pictures on the screen and one of the test words is heard from the headphones (or speakers). The child tries to identify it by pointing to one of the 6 pictures. Since AAST is an adaptive speech test, the response to the previous test word determines the level at which the next stimulus word is presented (Levitt, 1971). If the response is correct, the intensity decreases by 5dB (3dB in Noise) and if incorrect or there is no response, the intensity increases by 10dB (6dB in Noise). AAST stops automatically after 7 wrong answers and the SRT is automatically calculated by the AAST programme. The average testing time is approximately two minutes per test condition (Quiet, Noise). The tester has no role in the analysis, other than comparing the SRT to the calculated norms in that language.

Coninx (2005, 2008) has validated and normed the test on German children (4-12 years of age). He reported higher SRTs (approximately 10dB) in 4-year-olds than 11-year-olds. Additionally, 8-year-olds in his study performed as well as adults. This could possibly be due to lack of concentration in the younger children. Based on these findings, Coninx suggested that age and SRT are interdependent. Psychometric curve for AAST was 14%/dB for speech-in-noise measurement and was comparable to the Oldenburger Kinder Satztest (Wagener & Kollmeier, 2005) having slopes of 6-8%/dB in Quiet and 12-14%/dB in Noise. Other AAST versions report similar results. Offei (2013) reported slope values of 10.2%/dB for the Ghanaian version and with 8.2%/dB in Quiet, and 8.4%/dB for Noise in the Vietnamese version (Nguyen, 2017).

In summary, AAST is an interlingually valid and reliable standardised tool with the following advantages:

- Available in several languages
- Short testing time
- Closed-set task, suitable for young children
- Interactive display for interactive assessment of SRT
- Adaptive test, preventing ceiling effect
- Can be carried out in Quiet and in Noise
- Tests effectiveness of hearing aid and cochlear implants

2.6 Local situation in Malta

Although speech audiometry materials have been developed in several languages, there are currently limited normed materials available in the Maltese language that would enable testing of speech perception skills, especially in children. Thus, one of the purposes of this study was to develop materials that can be used to measure the SRT in children and adults whose native language is Maltese.

Audiological services were initiated approximately 40 years ago and took place mainly in government hospitals. The increase in awareness regarding hearing loss and ear care triggered the need to evolve in audiology and increase the number of professionals trained in the field. Major landmarks include the launch of the MSc. Audiology programme in 2012 by the University of Malta, the new Audiology department which opened within the new hospital, Mater Dei, in 2007, and the beginning of the Maltese Cochlear Implant Programme in 2006. In addition, the launch of the Malta Association of Audiology in 2017 was also a major step forward. Universal Newborn Hearing Screening, which started in 2021, was also a milestone in audiology in terms of identification and age of implantation.

2.6.1 The Maltese Language

Maltese is the national language of the Maltese archipelago, which consists of the islands Malta, Gozo (Għawdex) and Comino (Kemmuna). It is spoken by over 90% of the population aged 10 years and older (National Statistics Office, Malta 2014). Aside from Maltese, English is the only other official language of the country, with over 62% having a good command of it (National Statistics Office, Malta 2014). The majority of the Maltese population can therefore be classified as bilingual (Vella, 2013). In general, Maltese is used at home and within the community, whilst English is used in higher educational contexts (Rosner & Joachimsen, 2012). Most children residing in Malta can be classified as either simultaneous or sequential bilinguals. Whilst spoken English still carries a higher social status, the majority of children are exposed predominantly to Maltese and then to English (Grech & Dodd, 2008). Once children start school, they are simultaneously exposed to both languages (Gatt et al., 2013). However, the majority of children are either dominant in Maltese or English, mostly dependent on their family and community context. There is no language education policy in Malta, but schools are obliged to teach Maltese as a subject in order to be licenced to operate.

The Maltese language originates from Arabic, but it is the only Semitic language which is officially written in the Latin alphabet (Fabri, 2014). It has continued to evolve through contact with romance languages such as Sicilian, Italian, and later on, English (Cremona, 1990; Mifsud, 1992). This uniqueness reflects the history of different rulers that once occupied the islands (Rosner & Joachimsen, 2012). As other Semitic languages, Maltese is rich in consonants. A set of consonants, referred to as the 'root' of the word, carry a general meaning. For example, the root k-t-b carries the meaning of everything connected with “writing”. Maltese has 30 letters in its alphabet, 6 of which are unique to the Maltese language (ż /z/, ġ /dʒ/, ħ /h/, ċ /tʃ/, għ (mostly silent and ie /iː/) (Rosner & Joachimsen, 2012). Maltese phonology has a similar consonantal phonetic inventory to English. There are only two additional Maltese phonemes, /ʔ/ and /ts/, while the English /θ/, /z/ and /ð/ phonemes are not part of the Maltese inventory (Grech & Dodd, 2008). Maltese phonotactics also allow for consonantal clusters of both Semitic and Romantic influence (Grech & Dodd, 2008). Similar to English, Maltese syntax follows the SVO pattern (Subject Verb Object) but has a flexible word order. Furthermore, the adjective is placed after the noun (Brincat, 2011).

2.7 Objectives and Research Questions

The aim of research is to examine the validity and usefulness of current tools, and to develop new ones which are more sensitive and specific to our population. This study will give insight into paediatric and adult outcome measures for the local population through the following research questions and hypotheses.

The following objectives were proposed for this dissertation.

Objective 1: To translate and validate the LittlEARS® Auditory Questionnaire in the Maltese language on children aged 0-36 months

Objective 2: To construct, norm and validate the Maltese language version of the Adaptive Auditory Speech Test (AAST) in Quiet, Noise and in High frequency

In order to achieve the set objectives, the following research questions were raised.

Research Question 1: Are the norm curves of the Maltese version of the LittlEARS® Auditory Questionnaire comparable to the German norm curve?

Research Question 2: Are the norm curves of the Maltese version of the LittlEARS® Auditory Questionnaire comparable to other languages?

Research Question 3: What are the norms of AAST in Quiet for Maltese adults and children aged from 4 to 10 years old?

Research Question 4: What are the norms of AAST in Noise for Maltese adults and children aged from 4 to 10 years old?

Research Question 5: What are the norms of AAST in High frequency for Maltese adults and children aged from 4 to 10 years old?

3. METHODOLOGY

3.1 Developing Screening Tools for Infants and Children in Malta

3.1.1 LittlEARS® Auditory Questionnaire translation and back translation

The first and original version of the LittlEARS® Auditory Questionnaire was in German (Weichbold et al., 2005). This version was translated into English which has subsequently served as the basis for adaptation into several other languages. The English version of LittlEARS® Auditory Questionnaire was adapted into Maltese using the translation/back translation procedure recommended by the International Test Commission (Hambleton, 2001). The purpose of the back translation design was to keep the variable meaning of the test items in the questionnaire and, in addition, to get a linguistically correct version (Harkness, 2003). The International Test Commission Guidelines ensure the avoidance of serious errors which could occur during the translation process.

The adaptation into the Maltese language was carried out in two phases. The first was the translation phase, whilst the second was the evaluation phase. This was done by means of an expert appraisal method which ensures that the translated version of the text is linguistically equivalent and is of the best professional quality (Obrycka et al., 2009) The back translation design was applied using the following steps:

- Direct translation from English (source language) into Maltese (target language)
- Back translation from the target language (Maltese language version) into English
- Comparing the original English and Maltese back translations (Obrycka et al., 2009).

In total, 4 persons consisting of 1 university lecturer, 2 professional translators and 1 post-graduate speech and language therapist were recruited to translate the test items from English into Maltese. All the professionals were Maltese natives who were competent in both languages. They also had experience in working with children and expertise in test construction and adaptation.

Translations into Maltese from English were completed within two weeks. Following this, another professional translator and a post-graduate speech and language therapist, who was equally competent in both languages, was recruited to do a back translation from Maltese to English. The back translations were carried out independently and were completed within two weeks, after which they were sent via email attachment to the researcher in Germany.

The translations and back translations were deliberately sent to different professionals in order to ensure that members of the second group did not have prior knowledge of the text. This ensured a measure of reliability of the translations and back translations. The researcher read through the translations, corrected a few typographical errors, and sent the corrections back to one of the first set of translators for cross-checking. After this cross-checking had been completed the text was returned to the researcher in Germany.

In order to judge the accuracy of the ‘translated’ Maltese versions of the LittlEARS®, questionnaire, the researcher compared each of the items of the original English and the back translated English versions. This process included an item-by-item comparison which was aimed at finding out whether the items measured exactly the same auditory behaviour (Obrycka et al., 2009).

The most obvious difference is shown in Table 1 which points out the lack of differentiation between ‘listen’ vs ‘hear’ in the Maltese language since they are both translated as the same word. This phenomenon occurred in three instances, Questions 2, 6, and 15.

Table 1

Summary of Differences between Direct Translation and Back Translation of the Maltese version of LittlEARS®

2	Does your child hear somebody speak?	yes	no	Hears; waits and hears; looks at the speaker for a longer time
2	Ibnek/bintek jisma'/tisma' lil xi ħadd jitkellem?	iva	le	Jisma'; jistenna u jisma'; iħares lejn il-kelliem għal ħin itwal
2	Does your child listen to somebody speaking?	yes	no	Listens; waits and listens; looks at the speaker for a longer time
6	Does your child listen when the radio/CD player/tape player is turned on?	yes	no	Listening, turns toward the sound; is attentive, laughs or sings/talks along
6	Does your child hear when you switch on the radio/CD player/ tape?	yes	no	Hears; turns towards the sound; pays attention; laughs or sings/speaks 'with a song'
6	Ibnek/bintek jisma'/tisma' meta jinxtegħel ir-radju/is-CD player/it-tejp?	iva	le	Jisma'; idur lejn il-ħoss, joqgħod attent, jidħak jew ikanta/jitkellem 'ma' kanzunetta'
15	Does your child hear on the telephone and does he/she seem to recognise that someone is speaking?	yes	no	When grandma or daddy calls he/she picks up the telephone and "hears"
15	Does your child listen on the telephone and does he/she seem to recognise that someone is talking?	yes	no	When grandma or daddy calls the child takes the receiver and 'listens'
15	Ibnek/bintek jisma;/tisma; fuq it-telefon u hu /hi jidher/tidher li jkun/tkun qed jagħraf/tagħraf li xi ħadd ikun qed jitkellem?	iva	le	Meta ċċempel in-nanna jew il-papà, jaqbad/taqbad it-telefon u jisma/tisma

Secondly, a separate questionnaire for male and female respondents was created in order to minimise confusion as the sentences were too long and complex to follow. Following this, the questionnaires were sent for expert appraisal approval.

An evaluation of the translations was carried out by applying an expert appraisal method. The expert appraisal method provides evidence regarding the quality of the translated version and recommends ways to improve the final version (Obrycka et al., 2009). Two experts, an Audiologist, and a Speech Language Pathologist, both experienced in working with children, were recruited to appraise the test items. The appraisers were each provided with a set of evaluation forms to ensure that the evaluation was systematic and orderly. The task of the appraisers was to compare both English and Maltese versions of each test item (including the examples) in order to assess the extent to which both versions measured exactly the same auditory behaviour. The experts rated each test item on a numbered scale from ‘1’, indicating an inappropriate translation, up to ‘5’ for an ‘absolutely appropriate translation’. Additional confirmation of translations was done through qualitative comments. The ratings show that the translations were generally good.

Following the review, other 4 statements were identified for revision. In item 1, ‘Does your child respond to familiar sounds?’, ‘tal-ħoss’ (of the sound) was added to the description to decrease ambiguity. Similarly, item 10 ‘Does your child recognise acoustic rituals?’, had the English word ‘lullaby’ also added since the Maltese translation is rarely used. The descriptions of items 31 and 35 also included the English words ‘nursery rhymes’ and ‘lullaby’ respectively.

3.1.2 AAST Maltese version

The Adaptive Auditory Speech Test is a computer-based test that assesses the Speech Recognition Threshold. The procedure is minimally dependent on the person’s vocabulary. Six easy words are used, and the test subject has to point to a picture to identify the word. The test is already established in many languages. In German, Dutch, and English, for example, the test uses spondee words (such as airplane, toothbrush, football) or tri-syllable words in case of spondee words absence such as Spanish or Arabic (Coninx et al., 2009).

3.1.2.1 Criteria for selection of words

The criterion for selection of the 6 AAST words for the Maltese version was as follows:

- 3–4-year-old children know the meaning of the words
- 3–4-year-old children recognise a picture of the words

- The words must have the same prosodic pattern (number of syllables and stressed syllable): S-S (spondee), S-W-W (tri-syllable, first syllable stressed) or W-S-W (tri-syllable, second syllable stressed). [S=strong, W=weak].
- The words must be maximally different at the phoneme level. Preferably, the phoneme statistics should correspond to the frequency of occurrence in the particular language.

3.1.2.2 Frequency of occurrence of Maltese phonemes

In AAST, it is preferred that the phoneme statistics of all the 6 selected words should correspond to the frequency of occurrence in the particular language (Maltese). This means that the phonemes of all the 6 words must agree with the general distribution of consonants and vowels in the standard language (Mohammed, 2010). A thorough search of the Maltese literature shows that there is no distribution curve in the Maltese language. A distribution curve of Maltese vowels and consonants based on selected passages from a primary reader was therefore developed. The first chapter of a Maltese adult reading book was selected and used to develop the Maltese phoneme distribution curve. 80 lines of text were phonetically transcribed. The completed phonetic transcriptions were inserted into an Excel file, sorted, and put into groups. Each of the phonemes was then counted using the Excel software and the percentages for each class of phonemes (stops, fricatives, approximants, nasals/laterals, affricates /trills) were then calculated (Figure 3).

Following this, all the 6 selected AAST words were phonetically transcribed and distribution curves were drawn based on the phonemes. As shown in Figures 4 and 5, the consonant and vowel curves for the AAST words were then compared to the Maltese curves. The curves show that sound in AAST and main text were close except for the central vowels. AAST uses only 6 words. Therefore, it would be expected that phonemes in AAST words may not always approximate entirely to those of the mother language. Table 2 shows the words selected for the Maltese set.

Figure 3

Phoneme distribution in the Maltese Language

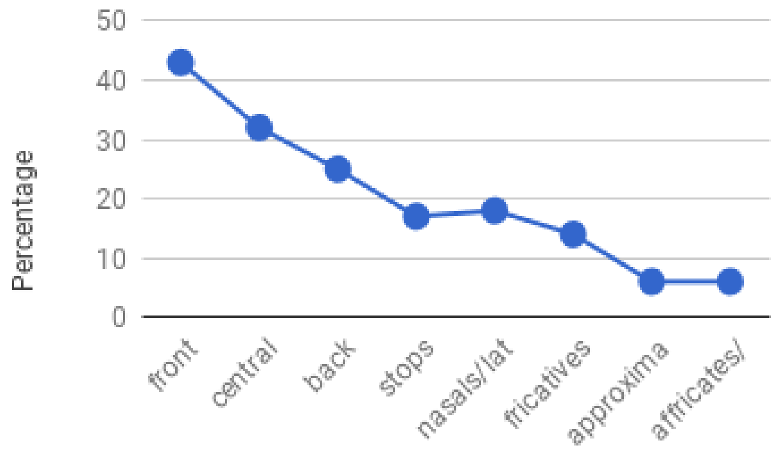


Figure 9

Vowel distribution in the Maltese Language vs AAST Maltese words

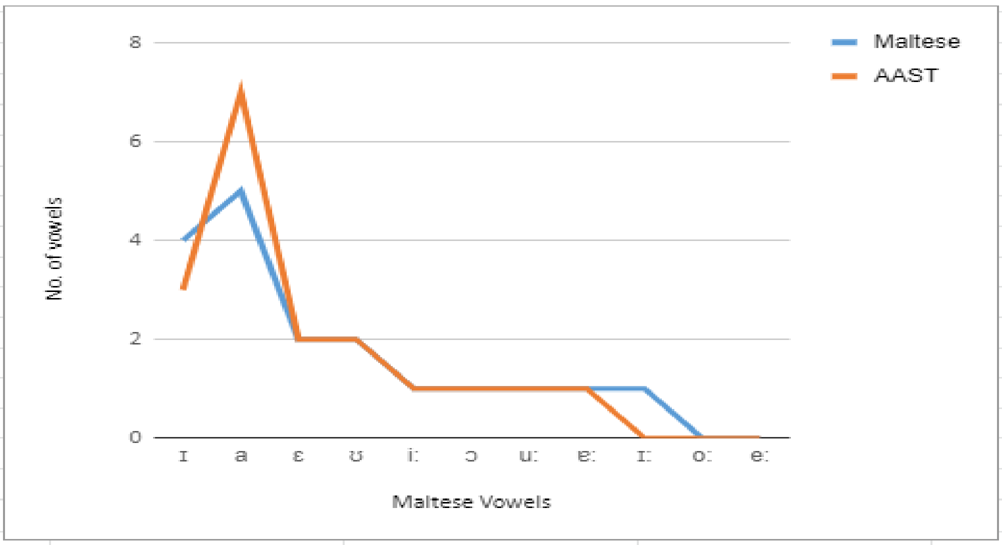


Figure 10

Consonant distribution in the Maltese Language vs AAST Maltese words

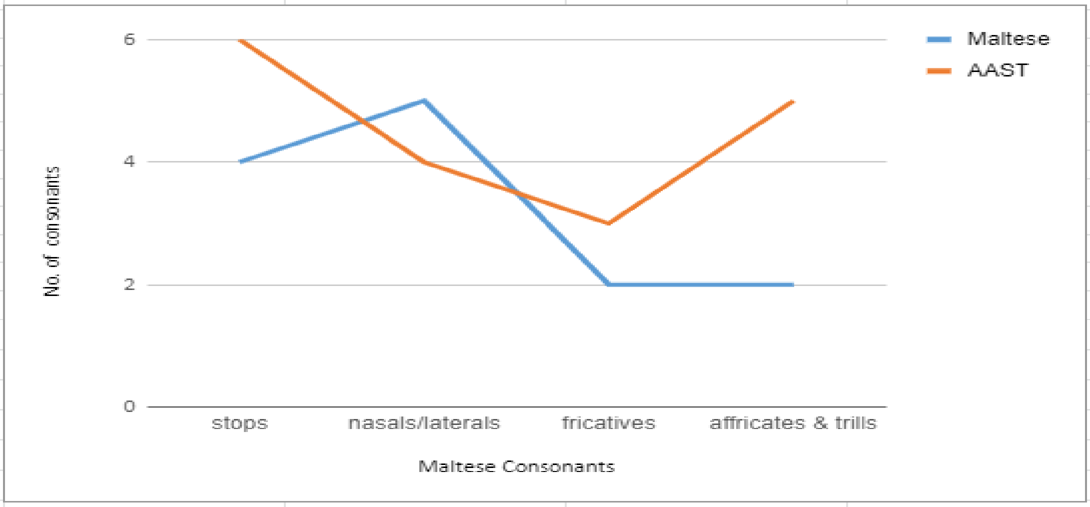


Table 2

Words chosen for the Maltese version of AAST

Word phonetic transcription	English translation	Prosodic pattern
kɐrɔtsɐ	car	W-S-W
nʊtʃɐ:lɪ	glasses	W-S-W
bebu:ʃʊ	snail	W-S-W
rɪgɐ:lɪ	presents	W-S-W
tʃɐvɛttɐ	key	W-S-W
ʃɐdɪ:nɐ	monkey	W-S-W

3.1.2.3 Criteria for selection of pictures

The selection of pictures for AAST was based on the following 3 criteria (Coninx, 2005; Offei, 2013, Nguyen, 2017); all pictures were in the same style, coloured and had the following details: JPG format, 201x174 pixels. The first set of selected pictures were tested with (N= 20) children aged 3-4 years old. More than 95% of the children recognised all of the pictures except for one. The picture was changed and following retesting, the word was replaced. After retesting, all of the pictures were deemed appropriate for the test. An interface of the pilot version of Maltese AAST is shown in Figure 6.

Figure 6

Interface of the pilot version of Maltese AAST

3.1.2.4 Recording of noise and sounds files

All the selected AAST Maltese words were recorded in Solingen, Germany. The sound files were recorded in a sound-proofed room with very minimal reverberation and ambient noise. The walls were covered with sound absorbing panels. The sound files were recorded with a high-quality microphone, a Sennheiser model E914 and digital recording equipment. The microphone was connected to a digital sound recorder TASCAM model DR-40X. The microphone was mounted on a shock mount with a plop filter. The files were recorded as mono (one microphone, one channel), with sounds digitized at 44.1 kHz and 24 bits and were stored on the computer in an uncompressed PCM wave (.wav) format.

A female speaker who had clear, natural pronunciation and an acceptable Maltese accent was used for the recordings. A female voice was the preferred choice for a couple of reasons. Firstly, in comparison with the pitch of men and children, the fundamental frequency (F0) of the female pitch as well as the formant frequencies (F1, F2) are “in the middle”.

Generally, F0-F1-F2 are lower for men and higher for children (Pépiot, 2015). Pépiot also found that consonants were proportionally longer in words produced by female speakers than by men, and they are likely to be more important than vowels in oral word recognition (Owren & Cardillo, 2006). Therefore, female speakers tend to produce “clearer” speech. Secondly, children have most experience with the voices of their mothers (female). Hence, internalized F1 –F2 information is more familiar or established for female speakers. Thirdly, female voices are more soothing. The speaker aimed to articulate all words clearly, without distortion of any sounds. She attempted to place equal emphasis on all parts of the word and maintain vocal effort throughout the words (Versfeld et al., 2000) while still retaining a natural intonation pattern. During the recording session, the speaker was asked to read out the list of 6 words twice. The recordings that best represented each of the 6 stimulus words were later chosen and saved separately from the original sound file. After the rating process, the intensity of each word was edited to yield the same intensity. It is advantageous to have stimulus words that are equally intelligible. If a highly intelligible item occurs several times during a test, the SRT will be unusually low, whereas if an item with poor intelligibility occurs several times, the SRT will be unusually high.

Unwanted silences preceding and following the recorded speech were eliminated. A calibration signal was also included, CCITT 1964. Speech-shaped noise was used as the masker since it is widely used for word-recognition testing (Shi & Canizales, 2013; Wilson & Oyler, 1997). For the purposes of creating noise files, the same speaker was recorded whilst reading aloud from a book for 2 to 3 minutes. The speech was used only to measure the long-term average speech spectrum, so the actual content of the speech was not relevant. The noise was generated by superimposing the speech material, which produces noise with the same long-term spectrum as the speech material. This creates speech shaped noise that best masks the speech material. Masking noise was continuous during the Noise test.

3.1.2.5 High frequency version

AAST assesses the SRT under Quiet and Noisy conditions. In this research study, the High frequency conditions will also be evaluated since restricted auditory perception of high frequencies has a negative influence on the ability to hear some elements of speech when compared to lower frequencies. This mostly includes voiceless plosives (stops) and especially fricatives. Earlier versions of the High frequency test included a set of 6 words differentiated only by a single phoneme such as fricatives or voiceless plosives (Nekes et al., 2016). Due to the lack of minimal pairs in Maltese, a whispered version of the Quiet test was used as an alternative.

3.1.2.6 Psychometric curves for Maltese AAST

AAST was tested on adult normal hearing individuals in Quiet, Noise and High frequency to check the internal balancing of the 6 words. The psychometric curve in Figure 7 shows the relation between the intensity sound level in dB SPL unit on the horizontal axis against the percentage of the correct answers of adults on the vertical axis. The presence of steep slopes in the psychometric curves signifies homogeneity among the 6 Maltese AAST words. Figure 8 displays the psychometric curves for The Maltese AAST in Quiet. This confirms that the intelligibility degree of the 6 words is close and that words are not significantly easier or more difficult than each other. After balancing, the steepness of the slope was 6.6%/dB.

Figures 9 and 10 display the average psychometric curves for the Maltese AAST in Noise and High frequency respectively. The steepness of the slope of the AAST in Noise is 14.3%/dB whilst in High frequency is 6% /dB.

Figure 11

Psychometric curves for the Maltese AAST words

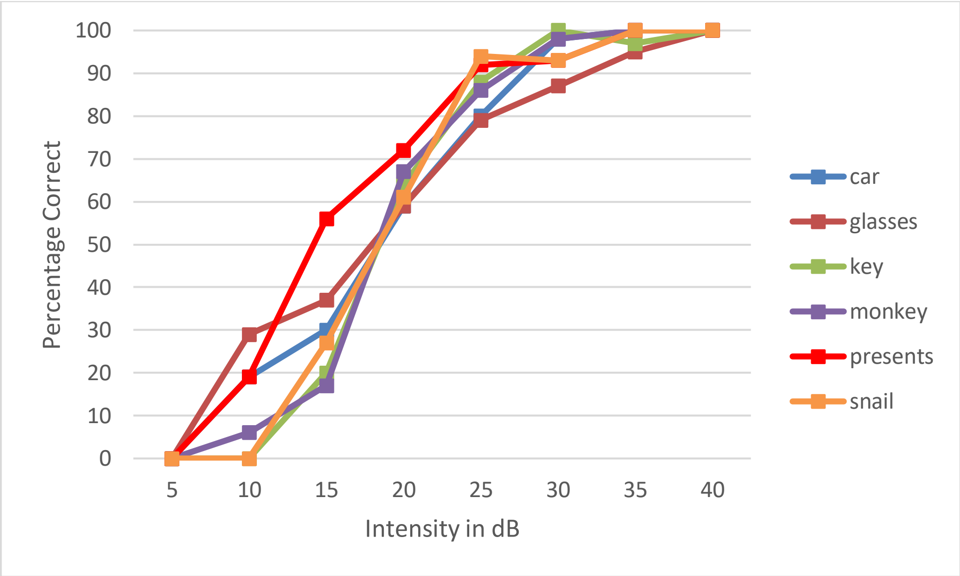


Figure 12

Average psychometric curves for the Maltese AAST words in Quiet

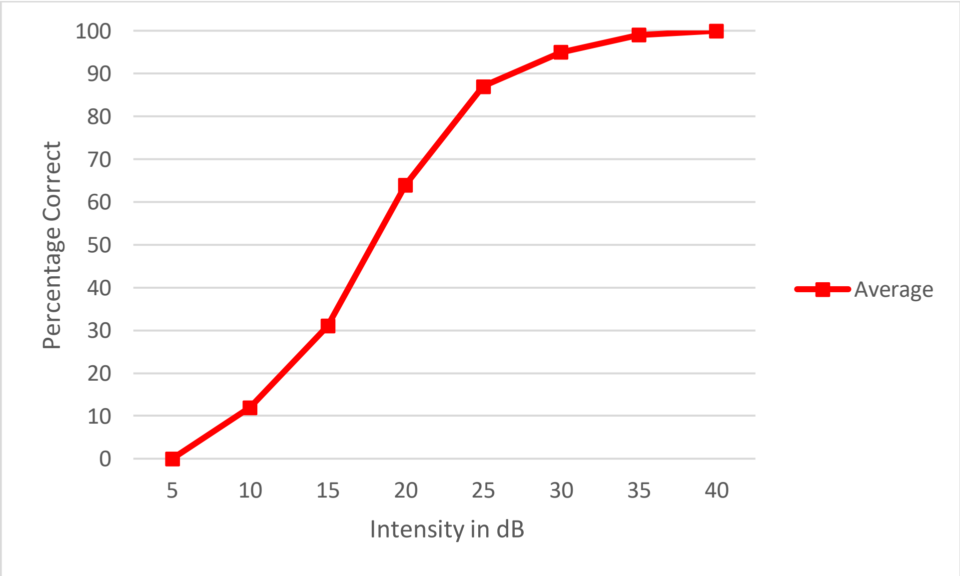


Figure 13

Average psychometric curves for the Maltese AAST words in Noise

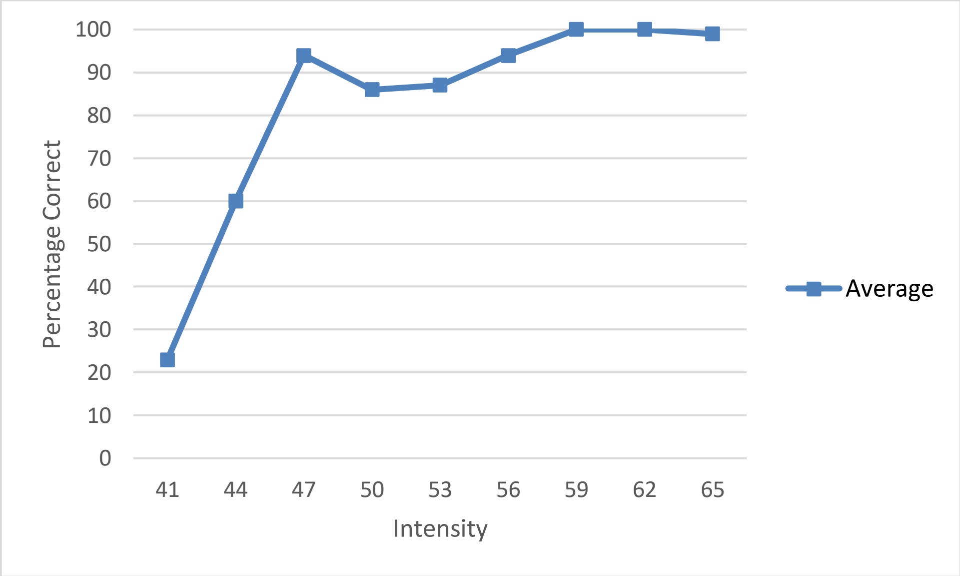
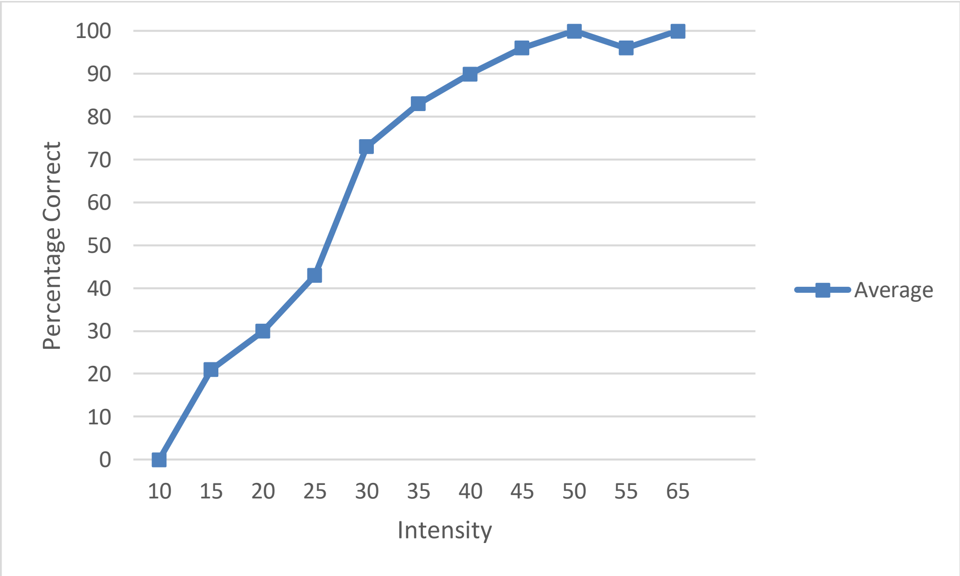


Figure 14

Average psychometric curves for the Maltese AAST words in High frequency



3.1.2.7 BELLS® platform

BELLS® platform is an acronym for “Battery for the Evaluation of Language and Listening Skills” (Coninx, 2018a). It is a software platform developed over the last two decades by Prof. Coninx at IfAP (Hoffmann et al., 2018). This platform is a test management system with a client database and test interfaces for several audiological tests and rehabilitation tools. The BELLS® database can be used for detailed inspection of the test results. Batch files can be created for randomisation, and the platform is flexible and suitable for research. By using an external microphone, it can also judge and reject test results based on ambient noise and can record client responses for later evaluation.

3.1.2.8 Preparation of pilot AAST basic versions

Pilot basic and whispered frequency versions of Maltese AAST were prepared at IfAP in Solingen, Germany. For the first field trial tests, data was collected from N=30 (N=60 ears) Maltese-speaking adults who had no indication of hearing loss. Each of these adult participants was tested with AAST on both ears separately. The data derived from this field trial were analysed. Based on the outcome of the analysis, the optimal word sets were determined. Significant changes were also made in the relative intensity levels.

3.2 Procedure

This section provides an overview of the research design employed in this study. It describes the ethical issues involved and provides information about the participants and the materials used. Additionally, it describes how the data was scored and analysed.

3.2.1 Study Design

The lack of outcome measures of speech perception in the Maltese Islands is the driving force underlying this study. The study design incorporates a quantitative research design, which is commonly associated with the positivist/post-positivist paradigm; a deductive approach in which a theory is first developed and then tested. Thus, as a quantitative study, it involves the collection and conversion of data into numerical form so that statistical calculations can be made, and conclusions drawn. This is done mainly through descriptive, correlational, quasi-experimental and experimental methods (Roberts, 2002). The aim of quantitative health research involves the discovery of relationships between variables and thus is able to discern any patterns or trends in the topic under investigation.

3.2.2 Consent and Ethics

The study was approved by the University Research Ethics Committee of the University of Malta since most of the data collection was carried out on children locally. Kindly refer to Appendix A. Permission was given by the nursery schools to distribute the information letters and consent forms to interested parents. Permission from the Data Protection Officer, CEO and Head Consultant of ENT and Audiology at Mater Dei Hospital was obtained in order to carry out the clinical tests (OAEs) on the children. (See Appendix B). In addition, permission was obtained from the Ministry of Education, Secretariat for Catholic Education, and respective head of schools to distribute information letters and consent forms to parents interested in participating in the validation of the Maltese version of AAST. (See Appendix C).

3.2.3 LittlEARS® Auditory Questionnaire

3.2.3.1 Recruitment of participants

In this cross-sectional study, 398 children aged between 5 days and 36 months were recruited from the local general hospital and from day nurseries in Malta. Recruitment of participants is essential for the success of a study. An accurate representation of the population is essential (Manohar et al., 2018). A sample of 398 participants selected randomly from a population of size approximately 12, 900 (4300 children are born in Malta per year) guarantees a maximum margin of error of 5% assuming a 95% confidence level. Inclusion criteria included the absence of known disabilities (hearing loss, neurologic disorder, and premature babies).

3.2.3.2 Procedure of data collection

The questionnaire, along with an information letter was delivered to the parents via the day nurseries staff and collected after 2 weeks. Participants were also recruited through the Medical Records Section or through the Breastfeeding Clinic at the local general hospital. Parents who were willing to participate were asked to fill in their details in the consent form provided. Kindly refer to Appendix D for the information letter and consent form. The questionnaire was self-administered by the caregivers and the researcher did not influence the process in any way. Further explanations of the statement/example were not allowed. The researcher did, however, take note of the statements which respondents found difficult. All children were screened using OAEs, an automated hearing test used in very young children. OAEs are a type of hearing test that measures an acoustic response produced by the inner ear. The test is performed by placing a small probe that contains a microphone and speaker into the child's ear. Sounds are generated in the probe and responses that return from the cochlea are recorded and represented pictorially on a computer screen as a PASS or REFER. Children who did not get a pass were referred to the relevant audiological services and were omitted from the study.

3.2.4 AAST

3.2.4.1 Recruitment of participants

A total of 208 children and 40 adults participated in this study. They were recruited from local government and church schools. Schools are a useful venue for recruiting children as they are at a receptive stage of life, whilst health promotion at these stages has great benefits (Manohar et al, 2018). Informed consent was received from parents. This is based on the Declaration of Helsinki which applies to all human subjects including adults and children (World Medical Association, 2001). Kindly refer to Appendix E for information letter and consent form. Non-Maltese speaking children were not included in the study since the test material was delivered in the Maltese language. Children with medical conditions including hearing loss, multiple learning disabilities and syndromes were also ruled out. Data from a number of children had to be excluded because of incomplete measurements due to insufficient compliance, inadequate knowledge of the Maltese language and erratic results probably due to the task being misunderstood. All 208 children had audiometric normal hearing (≤20dbHL) at all frequencies tested (500Hz, 1kHz, 2kHz, 4kHz). The mean Pure Tone Average for every age group and the number of children in each age group is tabulated below in Table 3.

Table 3

Number of participants for every age group and Mean PTA

Age	Number of participants	Mean PTA (dB HL)
4 years	40 (16 males, 24 females)	12.6
5 years	40 (24 males, 16 females)	10.3
6 years	38 (23 males, 15 females)	8.4
7 years	50 (22 males, 28 females)	7.3
10 years	40 (15 males, 25 females)	5.4
Adults	40 (16 males, 24 females)	5.2

3.2.4.2 Test equipment

The measurements were conducted in a quiet room at the local primary schools or in a sound-proofed audiometric booth at the paediatric audiology department of the local acute hospital. In the school rooms, care was taken to ensure that the ambient noise did not exceed

40dB (A). All testing was done using a Sennheiser HD 280 Pro closed circumaural headphone with a high ambient noise attenuation (<32 dB). The test words were presented through BELLS® software running on a Microsoft Windows 10 laptop with a touch screen for collecting responses. The audio signal to the headphone was delivered through an external NuForce uDAC-2 asynchronous 24-bit, USB Digital to Analog Converter – headphone amplifier. The volume control of the uDAC was set and fixed in the mid position.

3.2.4.3 Procedure

All three versions, Quiet, Noise and High frequency, were carried out during the same session in the mentioned order. The order of presentation was counterbalanced by having testing starting on the right side in half of the children and vice versa. Frequent breaks were given in between to prevent exhaustion especially in the younger children.

AAST was designed as a picture-pointing task on a touchscreen. The task involves starting the sound presentation by pressing the start button in the centre of the screen. One of the test words is uttered and the child needs to choose the presented item from a choice of 6 pictures on the screen, or to indicate that the item was not heard or not understood by pressing a question mark "?" button at the centre of the screen. As all other AAST versions, the sound presentation does not contain an introductory sequence such as "show me the ...". All the children were instructed and guided through the procedure carefully. Before starting the speech test, the child was made familiar with the test material by looking at the illustrations. This procedure ensured that the test items were part of the child's receptive vocabulary and that the images could be identified.

All participants were given the following verbal instructions to orient them to the nature of the task, to specify their mode of response, to indicate that the test material was speech, and to stress the need for the child to respond at faint listening levels (ASHA, 1988).

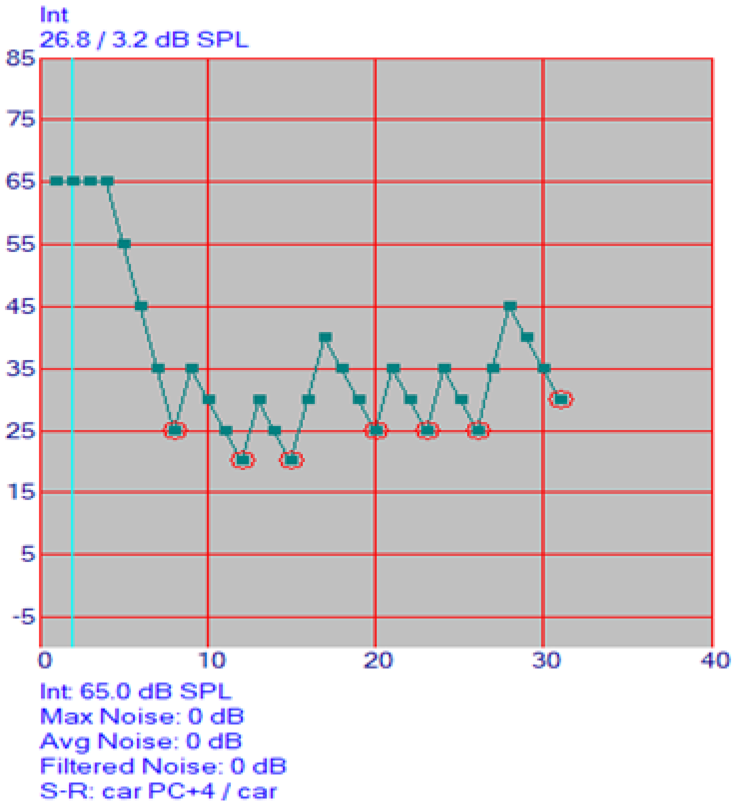
> *"You will hear words at a number of different loudness levels. For each word, listen carefully and then press the picture on the screen accordingly. At the very soft loudness levels, it may be difficult for you to hear the words. If you are not sure you may press the question mark button at the centre of the screen. If you have no answer/response, wait silently for the next word. Do you have any questions?"*

The presentation of the stimuli, the processing of the child's responses and the analysis were carried out by the AAST program. At the beginning of the test, the level was decreased in 10 dB-steps beginning from 60 dB until the first reversal occurs (incorrect or "?" input). After every correct answer, the next word was presented with 5 dB SPL lower volume (with speech in noise: 3 dB SPL). After every wrong answer, the volume was turned up by 10 dB SPL (with speech in noise: 6 dB SPL). This up-down-method adapts the presented stimuli to the speech recognition threshold in a quick and efficient manner. Figure 11 displays the Audiogram proceeding. The SRT result is calculated as the mean of the presentation levels. The programme stops automatically after 10 incorrect answers.

During the measurements, the Response Time was also determined for each response as the time from the word offset to the onset of the touchscreen response. The responses were recorded and time-logged automatically by the software. The intensity of the stimulus word as well as the number of correct and incorrect answers was automatically saved by the AAST software. Feedback as to the correctness of the response was not provided to the subjects.

Figure 15

AAST Result Interface



4. RESULTS

The purpose of this study was to translate and validate the LittlEARS® questionnaire for use with Maltese speaking parents or other caregivers, measure the psychometric properties of the developed Maltese version and to provide normative data for the interpretation of scores obtained for Maltese children. Secondly, this study aimed to develop and norm a Maltese version of AAST. The following is a summary of the results of this research study. SPSS for Windows v.21 software and Microsoft Office Excel 2016 were used for all analyses and graphs.

4.1 LittlEARS®

4.1.1 Descriptive statistics

Total amount of participants that was used for the analysis was 398; 20 were removed either due to a referral in the OAEs screening test or due to incomplete or invalid filling of the Maltese version of the LittlEARS® questionnaire**.** Figure 12 shows the age distribution across the different age groups. 268 children up to 24 months were included in the main analysis, whilst 130 130 children were used for evaluation of LEAQ as a screening tool in the third year of life (24-36 months). As depicted in Table 4 and Figure 12, 202 participants were males, whilst 196 were females.

4.1.2 Total Scores

The Kolmogorov-Smirnov and the Shapiro-Wilk Test were used to determine whether the total score distribution in children up to 24 months is normal or skewed. Please refer to Table 5. Both tests yielded *p* values (approximately 0) which are less than 0.05 level of significance indicating that the total score distribution does not satisfy the normality assumption. This is clearly displayed in the histogram below, Figure 13. For this reason, non-parametric tests were used to analyse the data.

Figure 12

Age Distribution of Participants

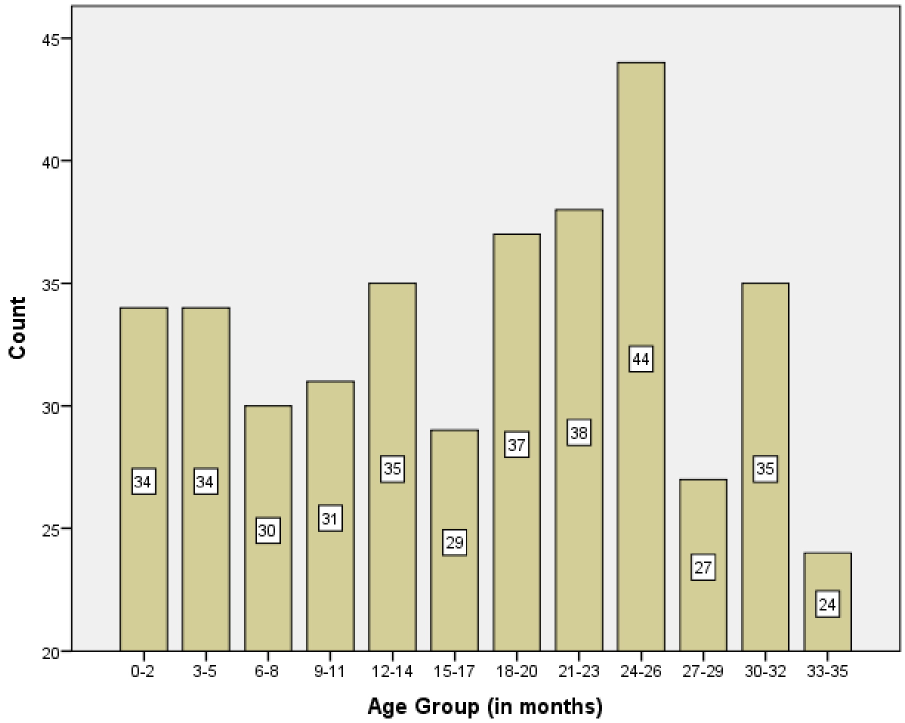


Table 4

Age Distribution of Participants by Gender

Age (months)	Males	Females	Total
0-2	18	16	34
3-5	16	18	34
6-8	10	20	30
9-11	11	20	31
12-14	17	18	35
15-17	16	13	29
18-20	24	13	37
21-23	19	19	38
24-26	22	22	44
27-29	11	16	27
30-32	22	13	35
33-35	16	8	24
Total	202	196	398

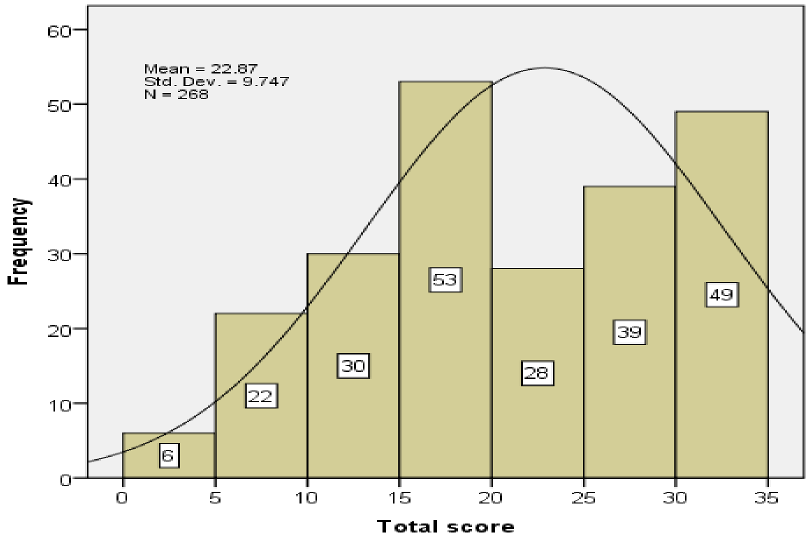
Table 5

Normality test for LittlEARS® scores

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total score	.113	268	.000	.924	268	.000

Figure 13

Total Score Distribution of normal hearing Maltese children up to 24 months



4.1.2.1 Total Scores by Age

4.1.2.1.1 Scale Analysis.

The predictive accuracy of the Maltese version of LEAQ was calculated using Guttman's lambda 2. A value of 0.921 was reported confirming a significant predictability. Adequate predictability is achieved with a value of 0.30. The split-half reliability coefficient for the Maltese version of LEAQ was 0.949 which indicates that the questionnaire has a high measuring accuracy.

The Cronbach's alpha coefficient value is 0.921 for the Maltese LEAQ. This suggests that the responses from subjects are greatly consistent across the questionnaire items. The values of the Cronbach's alpha coefficient seen demonstrate that the items of the Maltese version of LEAQ can reliably differentiate the degree of auditory development in the children evaluated in this study.

The correlation between age and total score was calculated to obtain information about the ability of the questionnaire to measure age-dependent auditory behaviour. Figure 14 shows a scatter plot of the total scores by age in months. The Pearson correlation coefficient is 0.903, which indicates a positive high correlation between scores and age. Thus, the older the child, the higher the child's expected score. This provides evidence for the validity of the Maltese version of the LEAQ. In addition, the above psychometric properties of the Maltese version were compared with those of the original German version as illustrated in Table 6. The results proved a high similarity between the two versions. The table also includes scale analysis of other languages for comparison.

Figure 14

Age distribution of normal hearing Maltese children (N=268) by total score

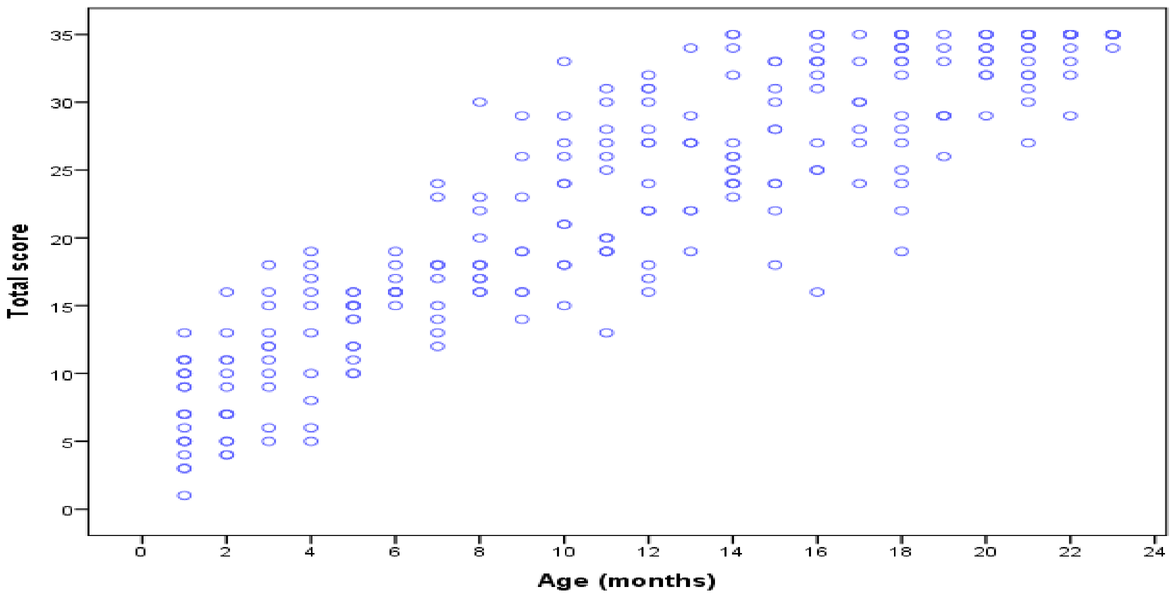


Table 6

Parameter comparison of the scale analysis between the Maltese version, the German version reported by Coninx et al (2009) and other language versions

LEAQ Version	Correlation age + Total Score	Guttman's Lambda	Split-half reliability	Cronbach's alpha
Maltese	0.90	0.92	0.95	0.92
German	0.91	0.93	0.88	0.96
Mandarin	0.84	0.88	0.91	0.95
Polish	0.90			0.95
Yoruba	0.78	0.58	0.70	0.91
Persian	0.81	0.96	0.73	0.96
Turkish	0.84	0.91		0.94

4.1.2.1.2 Item Analysis

Parameters and results of the item analysis are shown in Table 7.

4.1.2.1.2.1 Correlation between age and item score

Columns 2 and 3 in Table 7 show the correlation between age and item score. This was calculated to check the items' suitability for measuring the age-dependency of behaviour. The correlation coefficients range from 0.14 to 0.81. About one third of the items show a strong positive correlation with age ($r \geq 0.7$), while only a few are weakly correlated ($r \geq 0.3$). The average correlation is generally moderate. Items with a low coefficient have limited meaning for the child's age-dependent auditory response. Items 1-4 are intended for measuring auditory behaviour that even very young children can exhibit. Thus, it was not surprising for these questions to have a weak correlation with age. These items ensure that no child gets a score of zero. This was observed across several LEAQ versions (Kayedo, Adeyemo, 2018; Garcia Negro, Garcia, Quevedo, 2015; Spitzer & Zavala, 2011; Wang et al, 2013, Coninx et al, 2009) and hence were included in the Maltese version. While in this normative study these questions are non-contributory, the authors believe it is necessary to retain them against the future possibility that they will be useful when describing the behaviour of children with hearing loss that may not possess these skills.

4.1.2.1.2.2 Item Difficulty

The index of difficulty of each item on the questionnaire is also given in Table 7 (Columns 4–5). It displays the ratio of the number of subjects who give the ‘‘yes’’ response to the whole number of subjects (N=268). In this study, the indices ranged from 0.54 to 0.98, whilst the original German version ranged from 0.25 to 0.98. The Mandarin version, similarly, ranged from 0.31 to 1.00 (Wang et al, 2013), the Persian from 0.39 to 0.99 (Zarifian et al., 2019) and the Yoruba one ranged from 0.51 to 0.99 (Kayode et al, 2018). This shows that in all versions, the items of the questionnaire are almost presented in order of difficulty from the easiest items indicating basic auditory skills to the most difficult ones demonstrating advanced auditory skills. As mentioned earlier, questions with a high index of difficulty were kept in the questionnaire in order to avoid zero-points-scores.

4.1.2.1.2.3 Discrimination Coefficient

The correlation between an individual item and the total score on the questionnaire is referred to as the Discrimination Coefficient and is tabulated below (Columns 6-7). A high correlation value indicates that the item has a significant impact on the total score. This also helps in differentiating between good and poor performers. For instance, items 1 and 2 have the lowest correlation coefficients, suggesting that these particular items have limited contribution in distinguishing between good and poor performers. On the other hand, the other items show high discrimination values confirming that the Maltese version of LEAQ is able to differentiate between children displaying age dependent auditory responses.

Table 7

Parameter comparison of the item analysis between the Mandarin version and the German version of the LEAQ reported by Coninx et al. (2009)

Item no.	Corr. age + item score		Index of difficulty		Discrimination coefficient	
	Maltese	German	Maltese	German	Maltese	German
1	0.19	0.21	0.98	0.98	0.04	0.25
2	0.14	0.10	0.97	0.98	0.08	0.16
3	0.32	0.30	0.62	0.94	0.60	0.37
4	0.31	0.26	0.62	0.93	0.48	0.37
5	0.46	0.41	0.80	0.95	0.43	0.51
6	0.31	0.47	0.66	0.84	0.57	0.59
7	0.53	0.44	0.58	0.83	0.73	0.54
8	0.37	0.13	0.54	0.82	0.72	0.24
9	0.50	0.52	0.62	0.81	0.75	0.66
10	0.47	0.43	0.62	0.80	0.60	0.55
11	0.37	0.47	0.64	0.78	0.63	0.58
12	0.63	0.69	0.56	0.74	0.79	0.76
13	0.57	0.59	0.60	0.74	0.82	0.73
14	0.15	0.33	0.66	0.72	0.61	0.29
15	0.63	0.67	0.57	0.71	0.90	0.76
16	0.62	0.66	0.60	0.70	0.88	0.75
17	0.71	0.64	0.63	0.69	0.82	0.76
18	0.69	0.76	0.63	0.64	0.84	0.81
19	0.69	0.63	0.62	0.63	0.93	0.71
20	0.73	0.80	0.59	0.59	0.92	0.86
21	0.63	0.50	0.56	0.55	0.90	0.75
22	0.80	0.81	0.65	0.52	0.79	0.87
23	0.75	0.8	0.63	0.51	0.80	0.85
24	0.81	0.81	0.69	0.50	0.52	0.87
25	0.75	0.73	0.67	0.42	0.70	0.78
26	0.74	0.79	0.63	0.42	0.67	0.81
27	0.71	0.75	0.70	0.40	0.52	0.79
28	0.70	0.73	0.63	0.40	0.66	0.77
29	0.73	0.64	0.59	0.39	0.75	0.70
30	0.70	0.77	0.56	0.39	0.60	0.80
31	0.69	0.70	0.63	0.38	0.58	0.72
32	0.70	0.70	0.67	0.34	0.52	0.72
33	0.39	0.63	0.82	0.32	0.37	0.62
34	0.69	0.71	0.64	0.27	0.40	0.65
35	0.69	0.62	0.68	0.25	0.40	0.57
Average	0.57	0.58	0.65	0.63	0.64	0.64

4.1.2.1.2.4 Correlation between Age and Item Score

The Kruskall Wallis Test is a non-parametric test that compares mean total scores between groups of participants clustered either by gender/age. As seen in Table 8, the mean total score increases significantly between 1 and 24 months. However, the score remains fairly the same after the age of 24 months (*p* = > 0.05), as shown in Figure 15 and Table 9.

Table 8

Total Mean Score across the different age groups

Age (months)	Sample	Mean	Std. Deviation
0-2	34	7.74	3.387
3-5	34	12.62	3.790
6-8	30	17.87	3.608
9-11	31	22.42	5.365
12-14	35	26.11	4.993
15-17	29	28.86	5.019
18-20	37	31.51	4.161
21-23	38	33.95	1.931
24-26	44	34.16	1.599
27-29	27	33.96	1.743
30-32	35	34.51	.853
33-35	24	34.54	1.062
Total	398	26.60	9.655

Figure 15

Mean Total Score distribution of normal hearing Maltese children (N=268) by age group

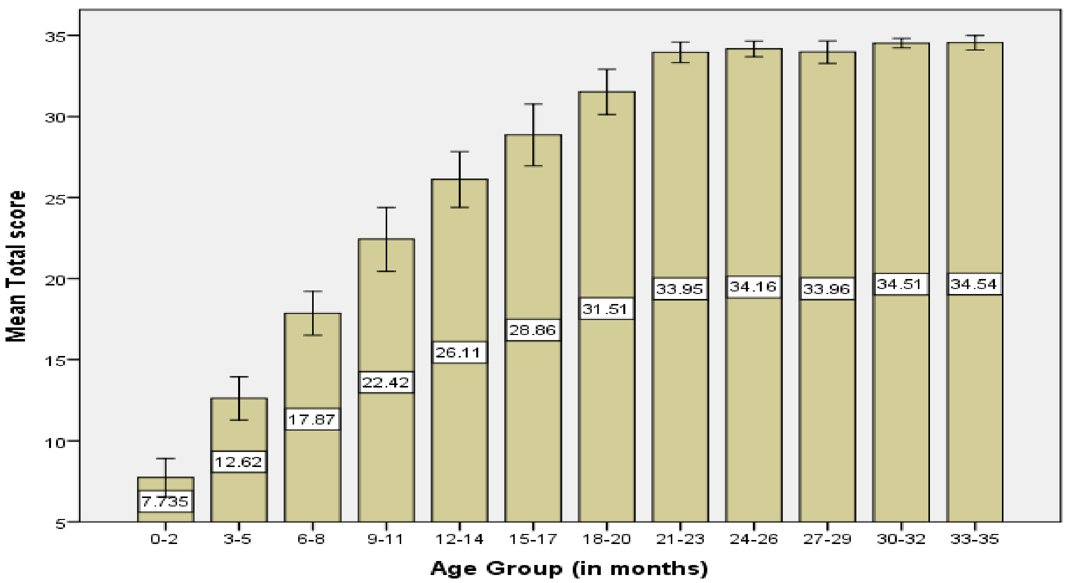


Table 9

Pairwise comparisons of Total Mean Score across the different age groups

Age Groups (months)	*p* value
0-2 /6-8	0.017
3-5 / 9-11	0.008
6-8 /12-14	0.012
9-11 / 15-17	0.026
12-14/ 18-20	0.005
15-17/ 21-23	0.000
18-20 /21-23	0.034
21-23 / 24-26	0.850
24-26/27-29	0.867
24-26 / 33-35	0.641
27-29 / 33-35	0.570
30-32 / 33-35	0.809

4.1.2.2 Mean Total Scores by Gender

The mean total score of males exceeds the mean total score of females by 0.6 scale points. However, this difference is not significant since the *p* value (0.366) exceeds the 0.05 level of significance. See Table 10.

Table 10

Kruskall Wallis test comparing total mean scores across males and females

Gender	Sample	Mean	Std. Deviation	*p* value
Male	131	23.18	9.956	0.366
Female	137	22.58	9.569	
Total	268	22.87	9.747	

4.1.3 Individual Item Scores

4.1.3.1 Individual Item Scores by Age Group

To check all of the items' suitability for measuring the age-dependency of behaviour, the correlation with their age group was calculated. As noted in Table 11, as the questionnaire items progress from 1 to 35, the percentage of correct answers decreases. On the other hand, the percentage of correct answers increases as the age increases. This confirms that the Maltese version of LEAQ is suitable for measuring the age-dependency of the behaviour.

Table 11

Chi Square test comparing item responses (yes) across age groups

Question /Age	0-2	3-5	6-8	9-11	12-14	15-17	18-20	21-23	*p*-value
1.	88.2	100	100	100	100	100	100	100	.000
2.	85.3	97.1	100	100	97.1	96.6	100	97.4	.017
3.	64.7	88.2	100	96.8	100	100	100	97.4	.000
4.	67.6	100	100	100	100	100	100	100	.000
5.	32.4	73.5	100	96.8	97.1	96.6	97.3	97.4	.000
6.	67.6	85.3	100	96.8	97.1	100	97.3	100	.000
7.	29.4	50	96.7	90.3	94.3	96.6	97.3	100	.000
8.	35.3	70.6	70	77.4	91.4	79.3	91.9	89.5	.000
9.	17.6	61.8	60	80.6	97.1	96.6	89.2	92.1	.000
10.	47.1	73.5	86.7	100	100	100	100	100	.000
11.	50	94.1	100	100	100	100	100	100	.000
12.	0	61.8	100	100	100	100	100	100	.000
13.	20.6	47.1	93.3	100	100	96.6	94.6	100	.000
14.	85.3	67.6	96.7	93.5	94.3	89.7	86.5	97.4	.002
15.	11.8	29.4	70	80.6	88.6	86.2	97.3	100	.000
16.	17.6	29.4	60	87.1	97.1	89.7	97.3	97.4	.000
17.	8.8	14.7	23.2	54.8	80	96.6	91.9	100	.000
18.	2.9	14.7	30	80.6	74.3	86.2	91.9	97.4	.000
19.	0	14.7	40	80.6	77.1	89.7	89.2	100	.000
20.	0	8.8	53.8	61.3	74.3	96.6	97.3	97.4	.000
21.	11.8	14.7	43.3	58.1	77.1	79.3	86.5	100	.000
22.	0	0	10	54.8	54.3	93.1	100	100	.000
23.	0	2.9	6.7	41.9	68.6	69	89.2	100	.000
24.	0	0	3.3	22.6	54.3	86.2	94.6	100	.000
25.	0	0	6.7	29	51.4	75.9	89.2	97.4	.000
26.	0	0	3.3	9.7	37.1	51.7	81.1	97.4	.000
27.	0	2.9	10	32.3	34.3	62.1	81.1	97.4	.000
28.	0	0	6.7	16.1	37.1	51.7	73	94.7	.000
29.	0	0	13.3	22.6	62.9	72.4	83.8	97.4	.000
30.	0	0	0	29	51.4	62.1	75.7	92.1	.000
31.	0	0	10	19.4	48.6	62.1	78.4	86.8	.000
32.	0	0	0	29	51.4	62.1	75.7	92.1	.000
33.	29.4	58.8	83.3	90.3	88.6	75.9	86.5	97.4	.000
34.	0	0	0	6.5	20	41.4	70.3	89.5	.000
35.	0	0	6.7	22.6	42.9	48.3	73	92.1	.000

4.1.3.2 Individual Item Scores by Gender

The Chi Square Test is used to investigate the association between the response (yes, no) for a particular question with gender/age group. As seen in Table 12, there were only three instances where there was a significant association between gender and response. In questions 9 and 17 males tended to respond ‘yes’ more than females, whilst in question 3, females tended to respond ‘yes’ more than males.

Table 12

Chi Square test comparing item responses across Males and Females

Question	Males Yes	Females Yes	*p* value
3. When somebody is speaking, does your child turn his/her head towards the speaker?	46.8%	53.2%	.011
9. Does your child respond with alarm when hearing an angry voice?	53%	47%	.021
17. Does your child know that a certain sound is related to a certain object or event?	54.4%	45.6%	.029

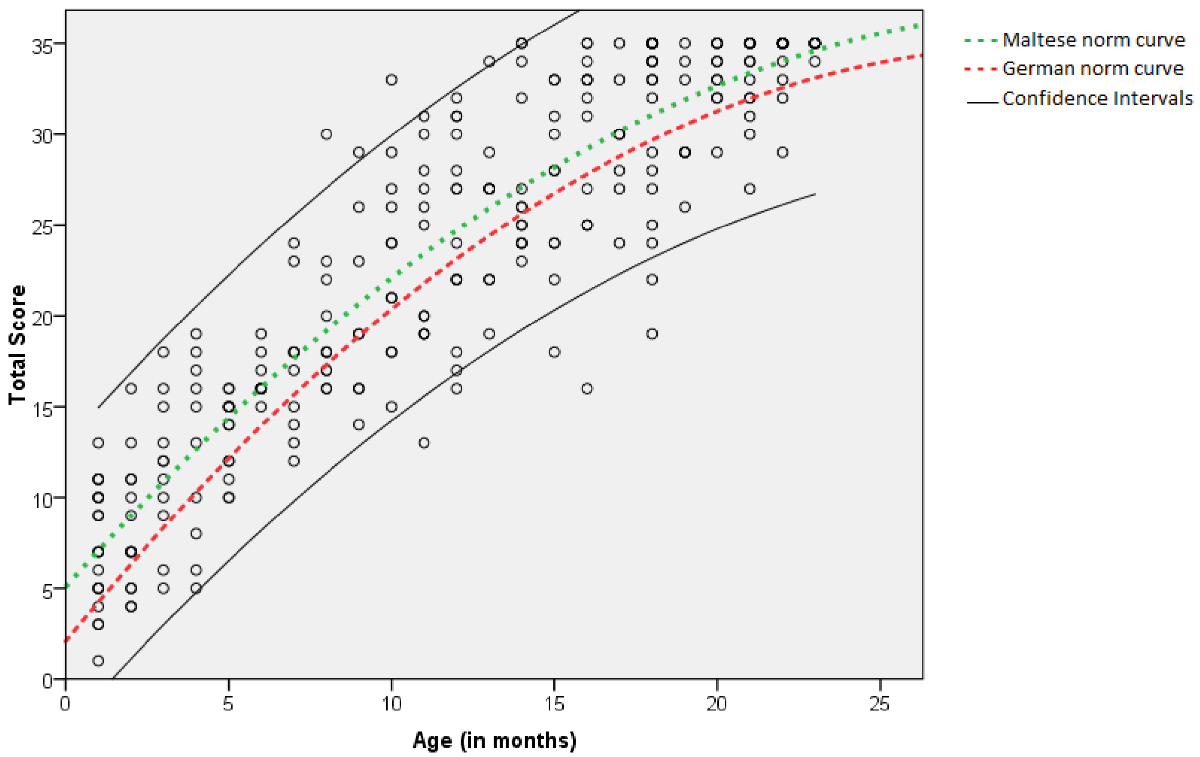
4.1.4 Generation of a Norm curve

To establish a norm curve for the development of auditory behaviour of Maltese children between 0 and 24 months of age, a regression analysis with ‘age’ as independent variable and ‘total score’ as dependent variable was carried out. A scatter plot of the raw data and the generated quadratic norm curve generated is shown in Figure 16. The minimum and maximum values are also provided. The regression equation for the Maltese sample is $y= -0.03\ x^2 +2.02x+5.07$, where the total score is represented by the variable y and age is represented by the variable x. The coefficient determination for this model shows that 82% of the variance in the total scores can be explained by age (R^2=0.82). The Maltese norm curve was also compared with the German norm curve, which was plotted using the regression equation of the German data, $y = -0.038x^2 + 2.22x + 2.07$. As seen in Figure 16, the coefficient of x and x^2 are very similar, which explains why the two curves are almost parallel. However, the constant terms (5.07 and 2.07) differ by 3 implying that the Maltese children are scoring 3 points higher, on average, than the German data.

Figure 17 shows the curve of the overall 15 languages from Coninx et al, (2009), derived from the equation, $-0.038x^2 + 2.163x + 3.470$. Similarly, one can note that the coefficients are very similar, and the constants differ very slightly (5.07 and 3.47) confirming how close the Maltese norm curve is to the other 15 languages validated by Coninx et al, (2009).

Figure 16

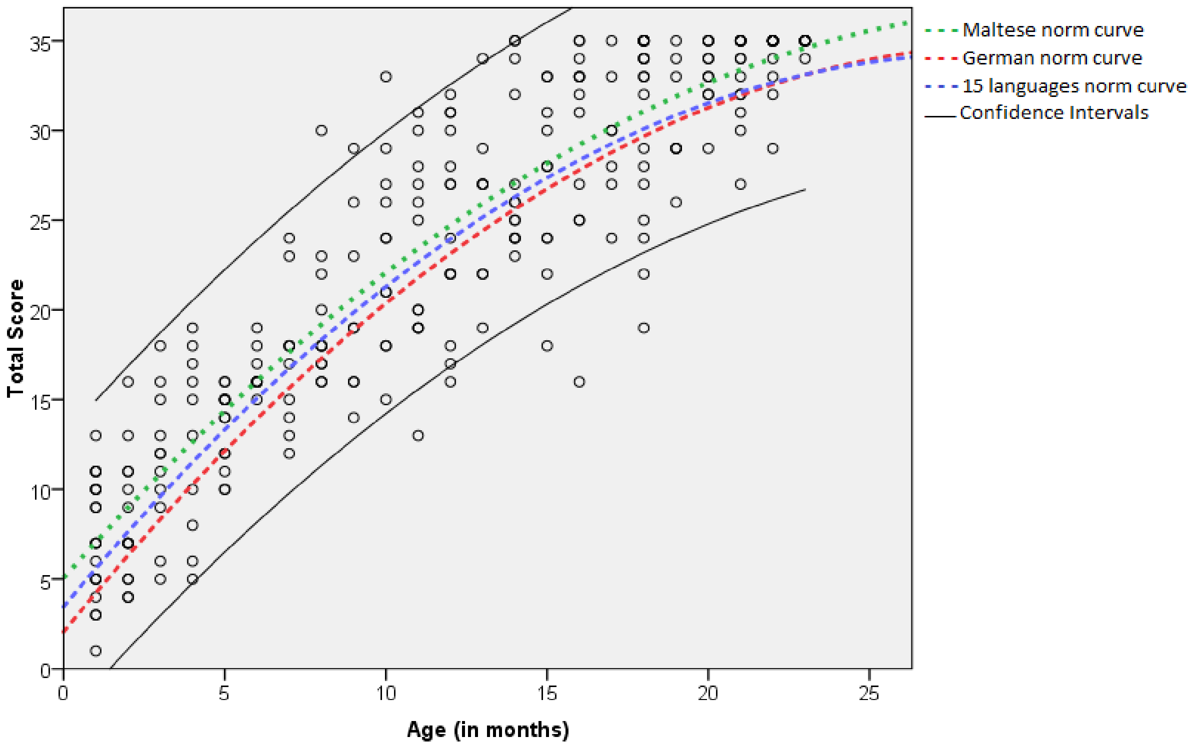
Regression curves (quadratic) with age as independent and total score as dependent variables in comparison to German data



Note. The green dotted line shows the Maltese normative curve whilst the red dashed line shows the original German curve. The upper and lower black lines display the upper and lower confidence intervals of the Maltese sample. The circles represent the raw data.

Figure 17

Regression curves (quadratic) with age as independent and total score as dependent variables in comparison to other languages



Note. The green line shows the Maltese normative curve whilst the red line shows the original German normative curve. The blue line corresponds to the overall normative curve for 15 languages respectively. The upper and lower black lines display the upper and lower confidence intervals of the Maltese sample. The circles represent the raw data.

4.2 Maltese version of AAST

4.2.1 Normative values

The normative values were obtained from data collected in 248 Maltese speaking children and adults. To determine the normative values of SRT, the participants' SRTs were averaged for each age group. In addition, the mean SRTs among the age groups were compared to observe the differences in the SRTs as age increases. The mean, standard deviation, minimum and maximum SRT values for Quiet, Noise and High setting for each age group are displayed in Tables 13, 16 and 19. Figures 18, 19 and 22 illustrate the overall thresholds in Quiet, Noise and High frequency respectively across ages.

4.2.1.1 Normative values in Quiet

As displayed in Table 13, the mean SRT threshold in Quiet decreases as the age increases. The standard deviation also decreases as age increases, indicating that the values are less spread out over a wider range, as evidenced in the minimum and maximum values. Large inter-individual variances of SRTs in young children are also clearly illustrated in Figure 18. The last column displays the average range where 68% of the population in that age group would score. For instance, 4-year-olds scoring between 24 (1 SD below the mean) and 40.6 dB SPL (1 SD above the mean) would be considered to be within the average range.

Table 13

Mean, Minimum, Maximum Thresholds, Standard Deviation in Quiet across age groups

Age (Years)	Mean (dB SPL)	Minimum (dB SPL)	Maximum (dB SPL)	SD	1 SD -/+	2 SD-/+
4	32.3	16.7	50.0	8.3	24.0 – 40.6	15.7 – 48.9
5	28.0	16.1	48.3	6.6	21.4 – 34.6	14.8 – 41.2
6	25.3	16.1	38.8	4.2	21.1 – 29.5	16.9 – 33.7
7	23.4	13.9	32.5	4.4	19.0 – 27.8	14.6 – 32.2
10	19.1	11.1	28.9	3.3	22.4 – 15.8	12.5 – 25.7
Adults	19.2	10.4	26.9	3.6	15.6 – 22.8	12 – 26.4

Note. One and two standard deviations above and below are also displayed.

The Kolmogorov-Smirnov and the Shapiro-Wilk Test were used to determine whether the SRT distribution in the participants is normal or skewed, see Table 14. Since distribution is non-normal, (p <0.05), non-parametric tests were used to analyse the data.

Figure 18

Mean SRT in Quiet across age groups

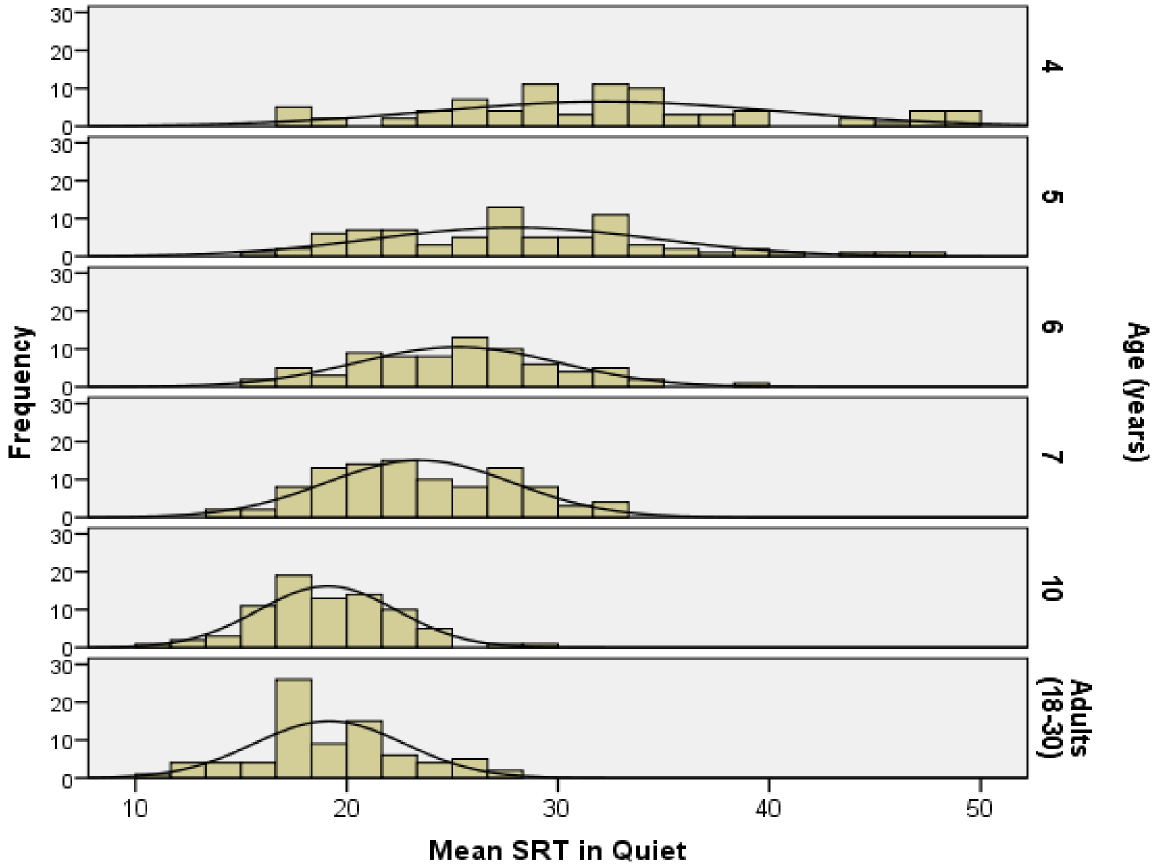


Table 14

Normality test for AAST scores in Quiet

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AAST score	.104	493	.000	.935	493	.000

The Kruskall Wallis Test is a non-parametric test that was used to compare AAST scores according to age. As seen in Figure 19 and Table 15, the SRT decreases significantly between 4-year-olds and 10-year-olds. No significant difference was reported between SRT scores in Quiet in 10-year-olds and adults, showing that children at age 10 years have the same thresholds as in adults.

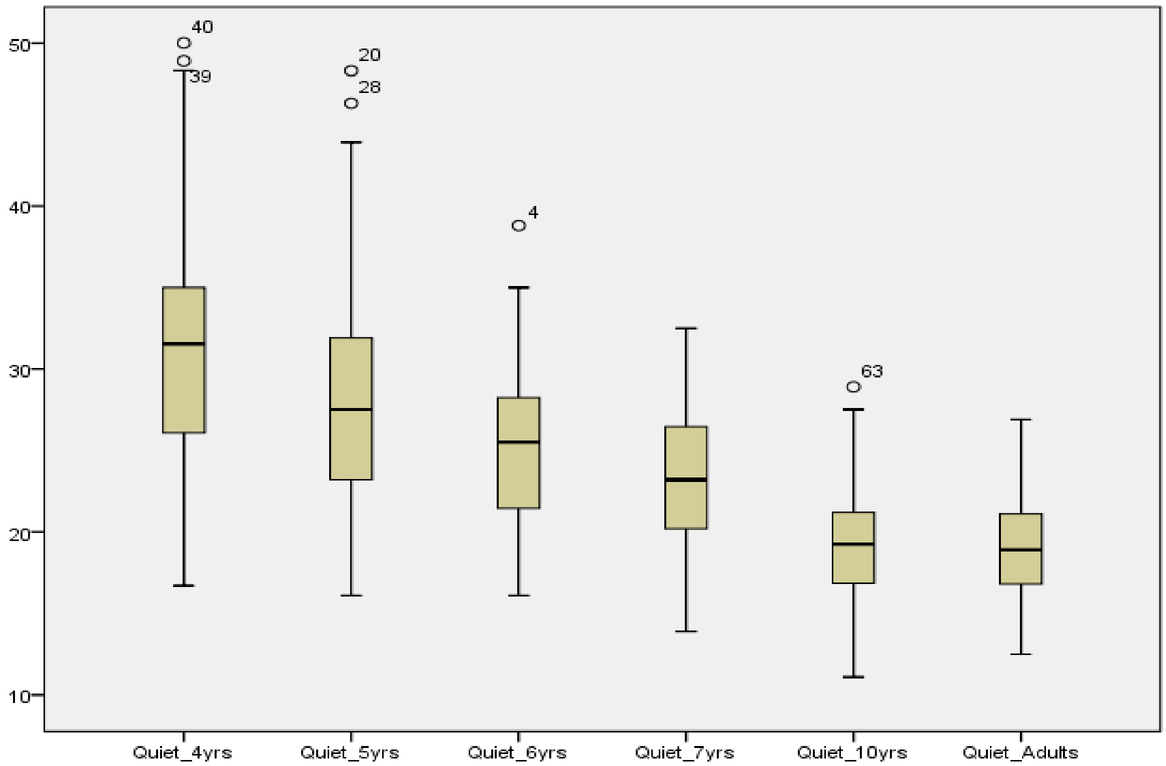
Table 15

Pairwise comparisons of AAST scores in Quiet across the different age groups

Age Groups	*p* value
4–5-year-olds	0.011
5–6-year-olds	0.069
5–7-year-olds	0.000
6–7-year-olds	0.049
7–10-year-olds	0.000
10-Adults (18-30)	0.916

Figure 19

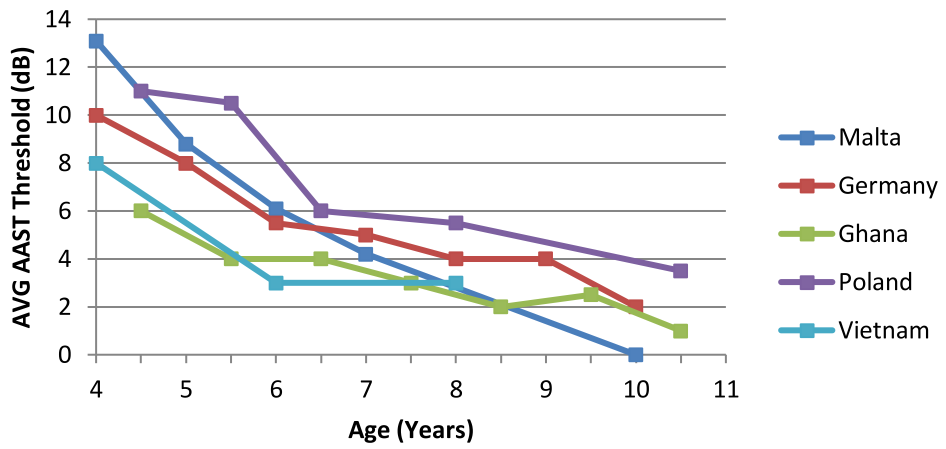
Comparison of Mean SRT values in Quiet across age groups



As seen in Figure 20, there is an age dependent threshold difference of about 13dB between younger and older children. These findings are also plotted against other AAST versions for comparison.

Figure 20

Age-related norm values in AAST across languages in comparison to the Maltese version



4.2.1.2 Normative values in Noise

Similarly to the thresholds in Quiet, the mean SRT threshold in Noise decreases as the age increases (See Table 16). The standard deviation also decreases as age increases, indicating that the values are less spread out over a wider range, as evidenced in the minimum and maximum values and in Figure 21.

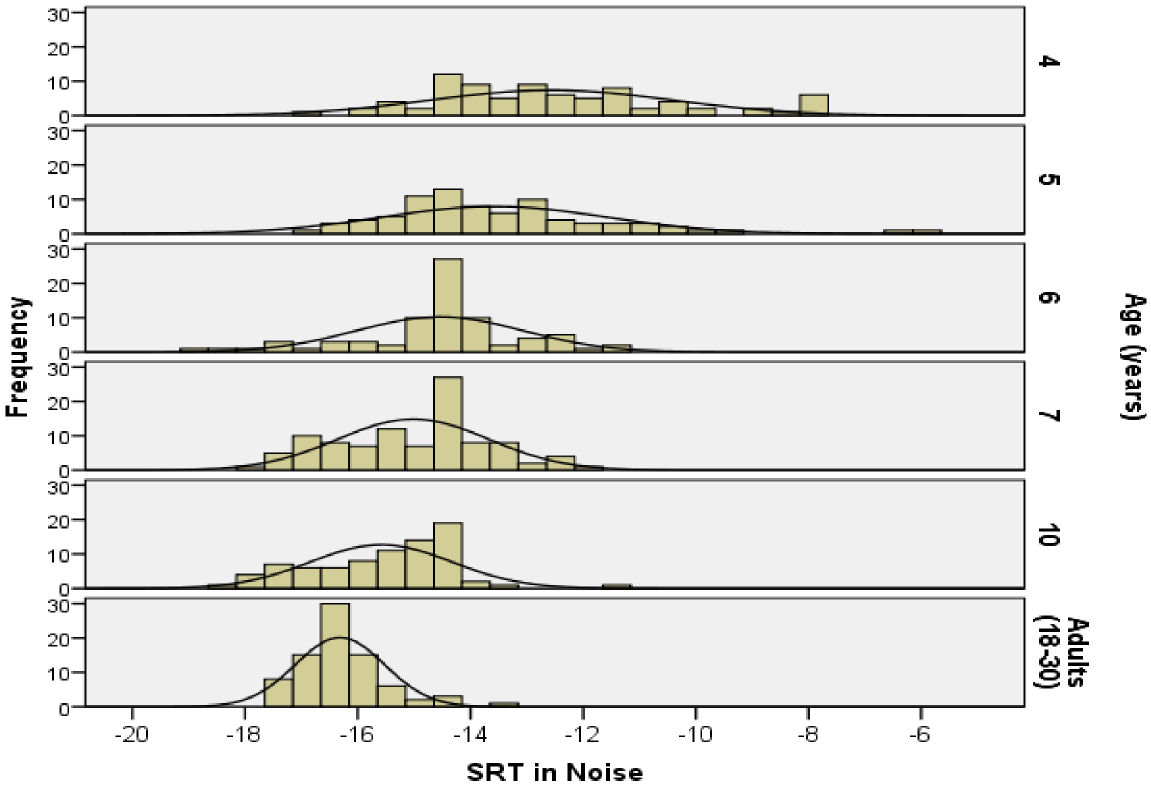
Table 16

Mean, Minimum, Maximum Thresholds and Standard Deviation in Noise across age groups

Age (Years)	Mean (dB SNR)	Minimum (dB SNR)	Maximum (dB SNR)	SD	1 SD -/+	2 SD-/+
4	-12.6	-7.8	-17.0	2.2	-10 to -14.8	-7.8 to -17
5	-13.6	-5.8	-16.8	2	-11.6 to -15.6	-9.6 to -17.6
6	-14.5	-11.2	-18.9	1.5	-13 to -16	-11.5 to -17.5
7	-15.0	-12.0	-18.1	1.3	-13.7 to -16.3	-12.4 to -17.6
10	-15.6	-11.6	-18.5	1.3	-14.3 to -16.9	-13 to -18.2
Adults (18-30)	-16.3	-13.4	-17.6	0.8	-15.5 to -17.1	-14.7 to -17.9

Figure 21

SRT in Noise across age groups



The Kolmogorov-Smirnov and the Shapiro-Wilk Test determined that distribution was non-normal, (p <0.05) and therefore non-parametric tests were used to analyse the data. (See Table 17). The Kruskall Wallis Test was used to compare AAST scores in Noise according to age. As seen in Table 18 and Figure 22, the SRT decreases significantly between 4-year-olds and adults.

Table 17

Normality test for AAST scores in Noise

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AAST score	.106	496	.000	.944	496	.000

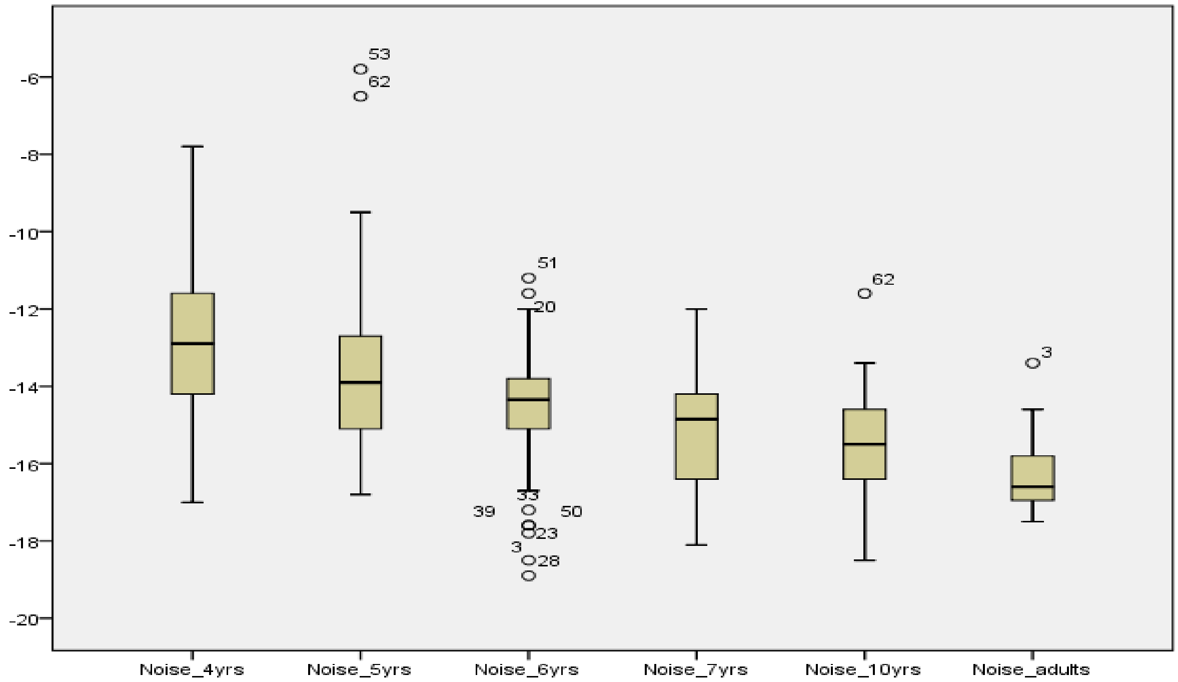
Table 18

Pairwise comparisons of AAST scores in Noise across the different age groups

Age Groups	*p* value
4–5-year-olds	0.010
5–6-year-olds	0.025
6–7-year-olds	0.034
7–10-year-olds	0.014
10-Adults (18-30)	0.002

Figure 22

Comparison of Mean SRT values in Noise across age groups



4.2.1.3 Normative values in High frequency

When tested in a High frequency setting, the mean SRT threshold decreases as the age increases (See Table 19). The standard deviation decreases mostly from 4-year-olds to 7-year-olds as shown in Figure 23, indicating that the values are less spread out over a wider range, as also evidenced in the minimum and maximum values.

Table 19

Mean, Minimum, Maximum Thresholds and Standard Deviation in High frequency across age groups

Age (Years)	Mean (dB SPL)	Minimum (dB SPL)	Maximum (dB SPL)	SD	1 SD -/+	2 SD-/+
4	41.5	23.9	63.8	9.2	32.3– 50.7	23.1–59.9
5	35.8	15.8	54.5	7.1	28.7–42.9	21.6–50.0
6	33.2	21.3	46.7	5.6	27.6–38.8	22–44.4
7	30.5	21.8	41.1	4.8	25.7–35.3	20.9–40.1
10	25.8	15.4	37.5	4.2	21.6–30	17-4–34.2
18-30	27.6	16.8	39.6	4.4	23.2–32	18.8–36.4

The Kolmogorov-Smirnov and the Shapiro-Wilk Test confirmed that the SRT distribution in the participants is non-normal, (p <0.05) and non-parametric tests were used to analyse the data (See Table 20). The Kruskall Wallis Test was used to compare AAST scores in the High frequency setting according to age. As seen in Figure 24 and Table 21, the SRT decreases significantly between 4-year-olds and older children. Similarly to the results in Quiet, there is no significant difference between SRT in 10-year-olds and adults.

Table 20

Normality test for AAST scores in High frequency

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AAST score	.104	493	.000	.935	493	.000

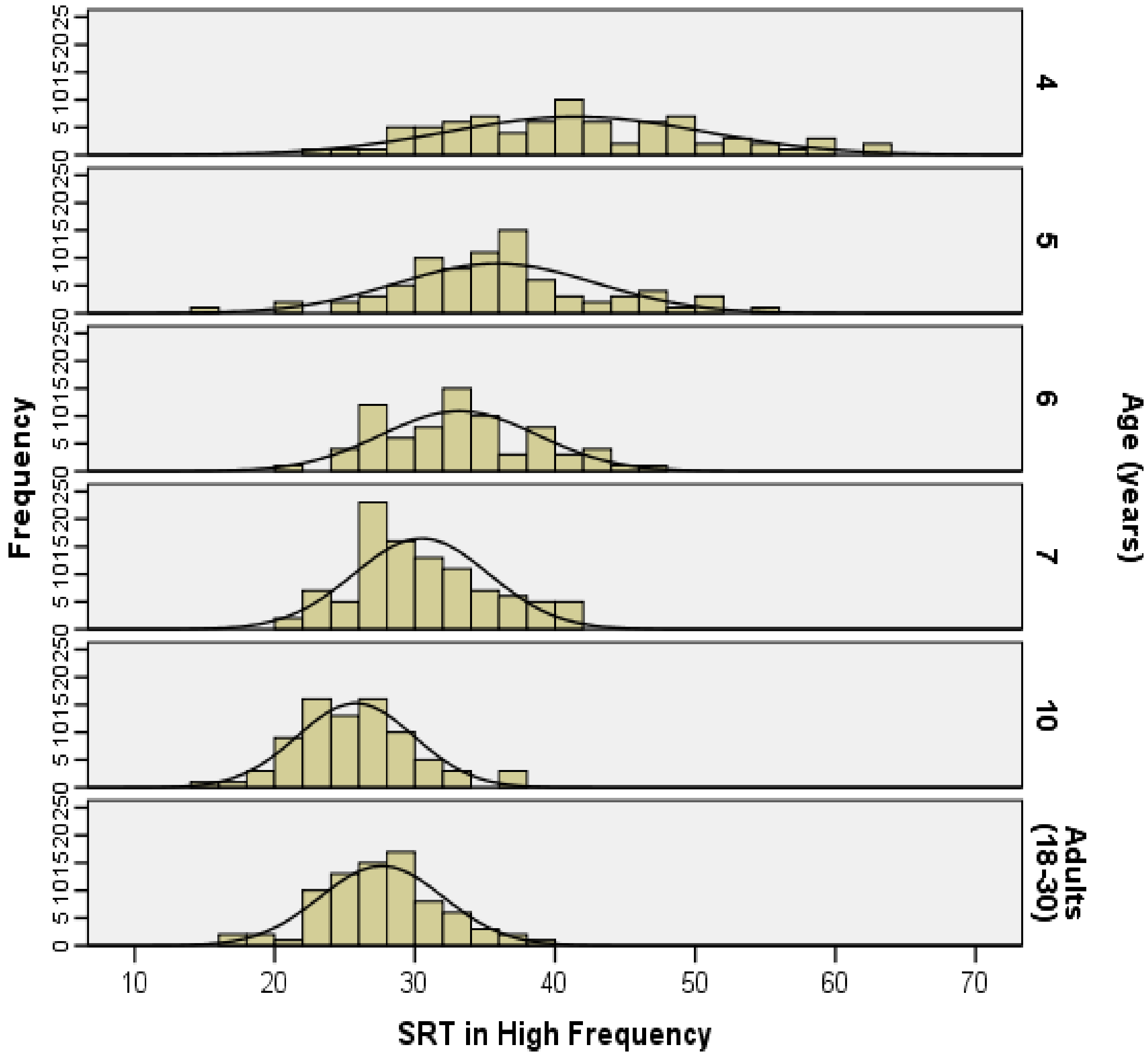
Table 21

Pairwise comparisons of AAST scores in High frequency across the different age groups

Age Groups	P-value
4–5-year-olds	0.011
5–6-year-olds	0.069
5–7-year-olds	0.000
6–7-year-olds	0.049
7–10-year-olds	0.000
10-Adults (18-30)	0.916

Figure 23

SRT in High frequency across age groups



4.2.2 Correlation between SRT values and PTA

A Pearson's product moment correlation was run to determine the relationship between the SRT values of listeners in Quiet and their pure tone average. Table 22 shows a summary of the results according to the respective age groups. Overall, a weak to moderate correlation is observed between SRT values in Quiet and the participant's PTA average. This means that an increase in the participant's PTA average is weakly to moderately correlated to an increase in SRT levels in Quiet.

Figure 24

Comparison of Mean SRT values in High frequency across age groups

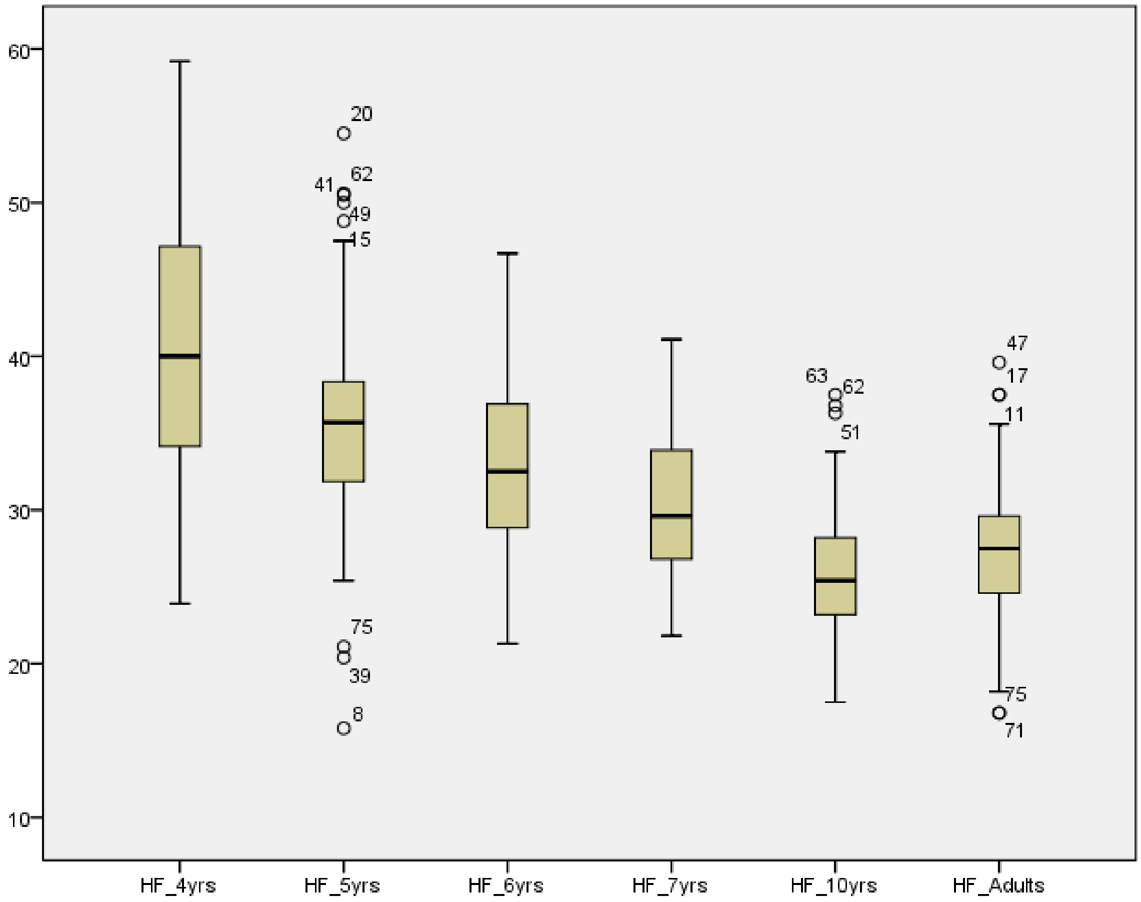


Table 22

Correlation of SRT values in Quiet and PTA

Age	Correlation Coefficient	p-value	Level
4 years	.395	.000	Weak positive correlation
5 years	.497	.000	Moderate positive correlation
6 years	.559	.000	Moderate positive correlation
7 years	.441	.000	Moderate positive correlation
10 years	.329	.003	Weak positive correlation
Adults	.375	.001	Weak positive correlation

4.2.3 Correlation between SRT values in Quiet and High frequency

A Spearman's rank-order correlation was run to determine the relationship between the SRT values of listeners in Quiet and High frequency settings. Table 23 shows a summary of the results. Overall, a moderate to strong correlation is reported between SRT values in Quiet and High frequencies.

Table 23

Correlation of SRT values in Quiet and High frequency

Age	Correlation Coefficient	*p* value	Level
4 years	.934	.000	Strong positive correlation
5 years	.380	.000	Moderate positive correlation
6 years	.025	.832	Correlation is not statically significant
7 years	.608	.000	Strong positive correlation
10 years	.399	.000	Moderate positive correlation
Adults	.141	.213	Correlation is not statically significant

4.2.4 Test-retest reliability in Quiet, Noise and High frequency

Ten participants were retested a week apart to determine test-retest reliability of the Maltese version of AAST. Paired sample t-tests showed that there is no significant difference between the initial and second retest in the Quiet (p = .656), Noise (p = .549) or High frequency setting (p = .573).

4.2.5 Comparison of Quiet, Noise and High frequency

On comparing the Mean SRT values across different test settings across several age groups, it can be noticed that in all three settings, the SRT values decreases as the age increases. The correlation between the SRTs and age in the children groups were estimated by a slope value of 2.2 dB per year in Quiet, 2.6 dB in High frequency and 0.5 dB in Noise respectively. As shown in Table 24, it can also be pointed out that there is an average difference of about 8dB SPL between SRT values in Quiet and those in High frequency.

Table 24

Summary of Mean SRT values in dB SPL in Quiet, Noise and High frequency across age groups

Age (years)	Quiet (dB SPL)	High (dB SPL)	Difference Quiet vs High (dB SPL)	Noise (dB SNR)
4	32.3	41.5	9.2	-12.6
5	28.0	35.8	7.8	-13.6
6	25.3	33.2	7.9	-14.5
7	23.4	30.5	7.1	-15.0
10	19.1	25.8	6.7	-15.6
Adults (18-30)	19.2	27.6	8.4	-16.3
Slope (dB difference/year)	2.2dB	2.6dB		0.5dB

4.2.6 Confusion Matrix analysis

A confusion matrix allows the recognition rates and confusions of stimulus words to be analysed. Confusion matrices were calculated for all age groups and settings (Quiet, Noise and High frequency) which were used in the research study. Each row of the confusion matrix corresponds to a specific presented stimulus word and each column corresponds to the word chosen by the listener. The diagonal highlighted elements denote the rates of correct recognised phonemes, and the non-diagonal elements denote confusion rates of stimulus words. The total in the tables does not always total to 100% as it does not include when answers were timed out or when the listener pressed the question mark sign ‘?’.

The confusion matrices in Tables 25, 26 and 27 show that there is minimal confusion between the six stimulus words across all of the test settings (Quiet, Noise and High frequency). The most confused stimulus overall is ‘glasses’, mostly pressed as ‘presents’ and vice versa. Nevertheless, the confusion is minimal and not significant to the purpose of this research study, confirming the suitability of these 6 words as homogeneously audible for speech testing. A detailed description of these results by age can be found in Appendix F.

Table 25

Maltese AAST Confusion Analysis for words in Quiet

		Answer					
		snail	key	car	glasses	presents	monkey
Stimulus	snail	73.7%	2.1%	1.7%	1.4%	2.0%	1.6%
	key	1.7%	72.7%	5.1%	2.1%	1.7%	2.3%
	car	2.3%	2.5%	68.4%	1.9%	2.1%	1.4%
	glasses	2.0%	1.8%	2.2%	69.0%	**7.3%**	1.3%
	presents	1.2%	0.9%	1.0%	**9.6%**	78.1%	1.7%
	monkey	1.7%	4.3%	1.9%	1.4%	2.3%	73.8%

Table 26

Maltese AAST Confusion Analysis for words in Noise

		Answer					
		snail	key	car	glasses	presents	monkey
Stimulus	snail	63.9%	2.8%	3.2%	2.9%	3.0%	2.3%
	key	3.0%	71.8%	2.3%	2.0%	3.4%	1.8%
	car	2.5%	1.7%	70.6%	2.2%	2.1%	1.3%
	glasses	2.1%	3.2%	2.0%	67.7%	**6.0%**	2.0%
	presents	1.3%	1.2%	1.7%	**7.2%**	76.1%	1.8%
	monkey	3.8%	4.3%	1.7%	3.6%	3.5%	65.9%

Table 27

Maltese AAST Confusion Analysis for words in High frequency

		Answer					
		snail	key	car	glasses	presents	monkey
Stimulus	snail	72.6%	1.8%	2.0%	2.1%	4.3%	2.5%
	key	2.9%	69.3%	3.4%	5.8%	3.2%	2.1%
	car	3.3%	2.3%	67.8%	2.8%	3.2%	2.7%
	glasses	4.2%	5.3%	2.7%	63.7%	**6.5%**	2.4%
	presents	3.2%	2.6%	2.6%	5.0%	69.0%	5.1%
	monkey	5.3%	4.3%	1.8%	3.4%	5.6%	66.9%

The confusion matrix also allows the possibility to examine which words are most likely to be timed out or elicit a '?' question mark response from the listener. Figure 25 shows that in Quiet, the stimulus word 'car' is the most likely to get timed out or elicit a '?' question mark, whilst the word 'presents' was the least likely one. In Noise, 'snail' was the most likely to get timed out or eliciting a '?' response, and again 'presents' to be the least likely to (Figure 26). In the High frequency setting, 'car' was the most likely to get timed out or elicited a '?' question mark (Figure 27).

Figure 25

The percentage words timed out or elicited a '?' response from the Maltese AAST words in Quiet

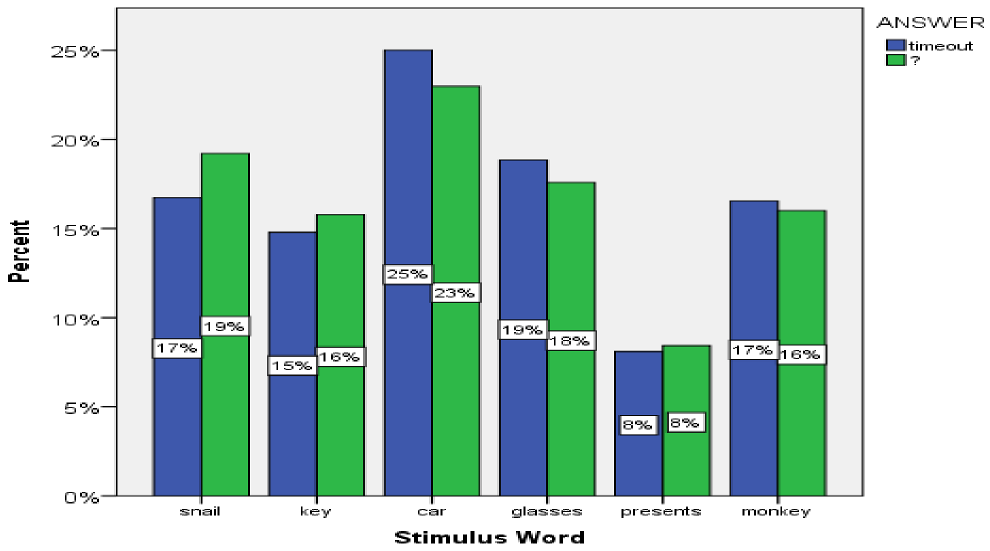


Figure 26

The percentage words timed out or elicited a '?' response from the Maltese AAST words in Noise

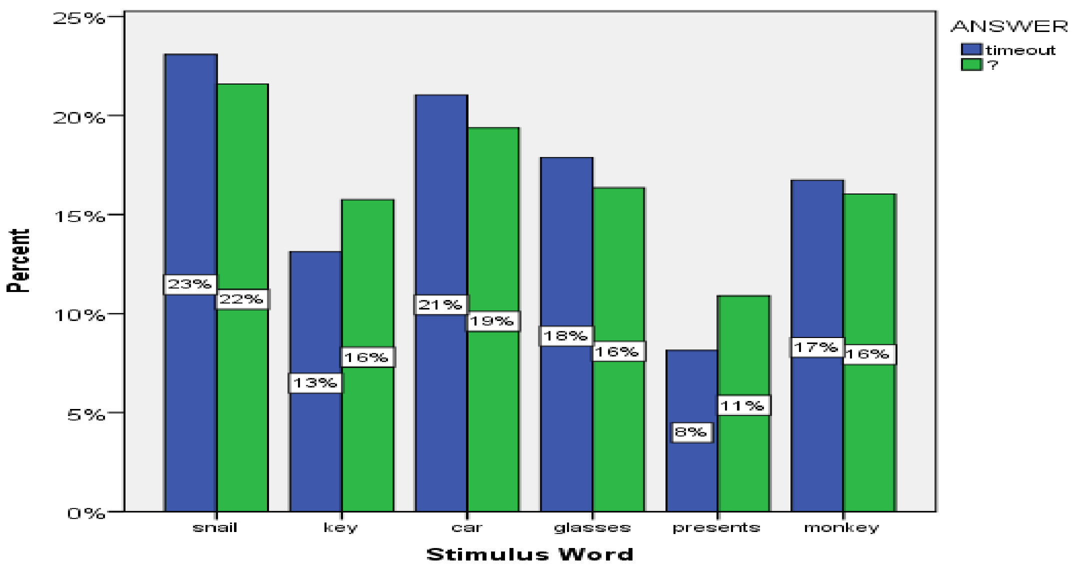
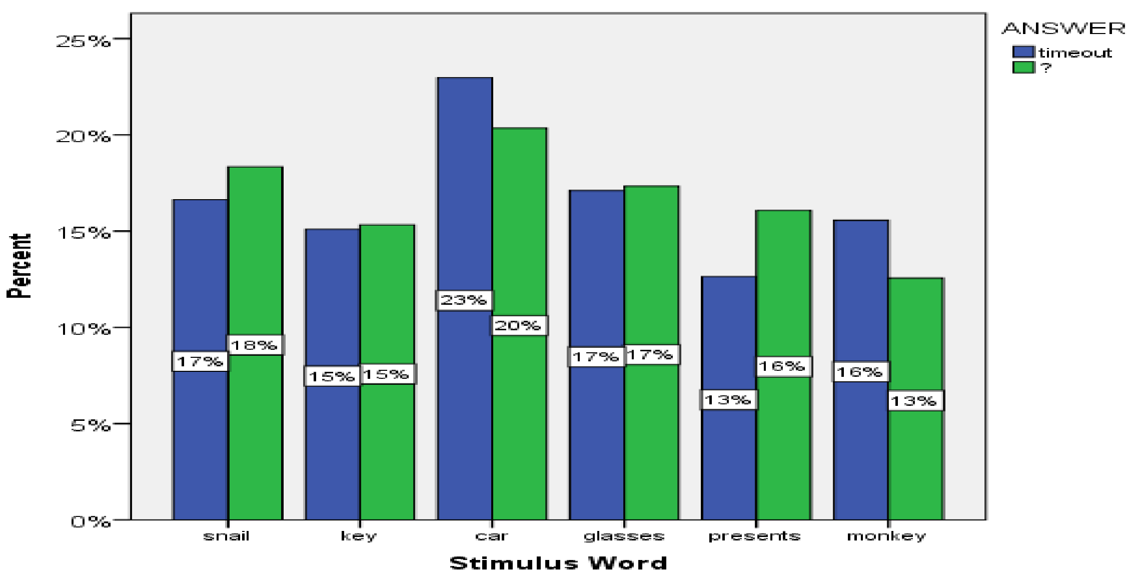


Figure 27

The percentage words timed out or elicited a '?' response from the Maltese AAST words in High frequency



4.2.7 Analysis of Correct responses

The number of correct responses were analysed according to the respective age groups. The crosstab results in Table 28 show that as age increases, the percentage of correct answers also increases. The chi square test confirms that the difference is statistically significant, X^2 (5, N=248) = 58.936, p = .000)

Table 28

Percentage Correct Responses for Maltese AAST according to age

	Age					
	4	5	6	7	10	Adults
Correct	68.2%	69.9%	70.9%	71.4%	72.4%	73.4%
Wrong	31.8%	30.1%	29.1%	28.6%	27.6%	26.6%

The number of correct responses were also analysed according to the test setting they were carried in. Table 29 shows that the least correct answers are in Noise, followed by High frequency and most correct answers were scored in Quiet. As seen in the chi square tests in Table 29, this is statistically significant across all ages, except in adults ($p > 0.05$). In adults, there is no statistically significant difference in correct answers in different settings.

Table 29

Percentage Correct Responses for AAST in Quiet, Noise and High frequency settings according to age

Age	Quiet	Noise	High frequency	Chi-square value	df	*p*-value
4	70.4%	66.5%	67.6%	8.887	2	.012
5	71.3%	67.9%	70.2%	6.498	2	.039
6	72.6%	68.7%	71.1%	8.066	2	.018
7	73.2%	69.1%	71.7%	12.273	2	.002
10	74.1%	70.2%	72.7%	9.000	2	.011
Adults	74.3%	73.4%	72.6%	1.815	2	.404

4.2.8 Analysis of Response Time

In this research, Response Time is taken as the time from the word offset to the onset of the touchscreen response. Table 30 shows the mean response time and other descriptive statistics. The negative response time is probably due to the fact that children may press the picture before the stimulus word ends, questioning whether the child has guessed it rather than listened attentively to it.

Table 30

Descriptive statistics for Response Time (ms) in Maltese AAST responses

	N	Mean	Minimum	Maximum	SD
Response Time	44129	1961	-19736	27550	905

4.2.8.1 Response Time according to age

An Independent Samples Kruskal-Wallis Test showed that there was a statistically significant difference in the distribution of response time across the age categories ($\chi2$ (5) = 2763.293, p = 0.000). Follow-up tests were conducted to evaluate pairwise differences among the 6 groups. As seen in Table 31, there is a significant difference between all age groups, except 5- and 6-year-olds (p = .537). This confirms that response time decreases as age increases.

Table 31

Response time (ms) for Maltese AAST according to age groups

Age	N	Mean	SD
4 years	7265	2100	1275
5 years	7104	2076	928
6 years	6677	2064	847
7 years	8775	2007	784
10 years	6994	1887	752
Adults	7006	1609	621

4.2.8.2 Response Time according to test setting (Quiet, Noise, High frequency)

Independent Samples Kruskal-Wallis Tests showed that there was no statistically significant difference in response time between the different test settings in 4-, 5- and 6-year-olds. There is however a significant difference in older children and adults. Refer to Table 32.

Table 32

Independent Samples Kruskal Wallis results for response time in Quiet, Noise and High frequency across the different age groups

Age Groups	*p* value
4 years	.117
5 years	.552
6 years	.793
7 years	.003
10 years	.000
Adults (18-30)	.000

In 7-year-olds, follow-up pairwise comparison tests show that there is a significant difference between response time in Noise and High frequency and between Quiet and Noise (Table 33). As seen in the mean ranks Table 34, the response time in Noise is significantly longer than that in High frequency.

Table 33

Pairwise comparisons of Response Time across the different test settings, Quiet, Noise and High frequency in 7-year-olds

Test Setting	*p* value
Quiet-Noise	.050
Quiet-High	.129
Noise-High	.001

Table 34

Mean Ranks of Response time according to age groups across different test settings

Age	Test type	N	Response Time Mean Rank
4 years	Quiet	2570	3625
	Noise	2269	3572
	High	2426	3698
5 years	Quiet	2565	3565
	Noise	2164	3578
	High	2375	3516
6 years	Quiet	2347	3334
	Noise	2026	3362
	High	2304	3323
7 years	Quiet	3049	4383
	Noise	2627	4515
	High	3099	4285
10 years	Quiet	2438	3504
	Noise	2125	3689
	High	2431	3323
Adults (18-30)	Quiet	2385	3353
	Noise	2203	3627
	High	2418	3539

In 10-year-olds there is a significant difference between all the 3 test settings (See Table 35). The mean ranks table 34 shows that response time is significantly longer in Noise and shortest in the High frequency test.

Table 35

Pairwise comparisons of Response Time across the different test settings, Quiet, Noise and High frequency in 10-year-olds

Test Setting	*p* value
Quiet-Noise	.002
Quiet-High	.002
Noise-High	.000

In adults, there is a significant difference between Quiet and Noise tests, and between Quiet and High frequency tests (Table 36). The mean ranks table 34 shows that response time is least in Quiet and longer in Noise and High versions.

Table 36

Pairwise comparisons of Response Time across the different test settings, Quiet, Noise and High frequency in Adults

Test Setting	*p* value
Quiet-Noise	.000
Quiet-High	.001
Noise-High	.145

4.2.8.3 Response Time according to Stimulus Words

An Independent Samples Kruskal-Wallis test showed that there is a statistically significant difference in response time between the 6 stimulus words ($\chi 2$ (5) = 766.755, p = 0.000). The mean ranks of stimulus words is tabulated below (Table 37). A pairwise comparisons test showed that there is a significant difference across almost all stimulus words, except car-key (p = .0854) and presents-monkey (p = .123). Response time is thus longest in 'glasses' followed by 'snail', 'monkey' and 'presents', 'key' and 'car'.

When age is accounted for, the stimulus word 'glasses' has statistically the most significant longest response time across all age. Overall, the stimulus words 'key', 'car', 'presents', have the shortest response time, whilst 'snail' and 'monkey' have a medium response time. A detailed analysis can be found in Appendix G.

Table 37

Mean Ranks of Response time across the 6 stimulus words (Age is not accounted for)

Stimulus Word	N	Response Time Mean Rank
glasses	7323	25489
snail	7358	22501
monkey	7188	21844
presents	7368	21518
key	7361	20562
car	7531	20524

4.2.8.4 Response Time according to Correct/Wrong Answer

A Mann-Whitney U test showed that there was a significant difference (U = 175377990.0, $p = 0.000$) between the response time for correct answers when compared to the response time for wrong answers. The median response time for correct answers was 21270.66 compared to 24014.36 for wrong answers suggesting that the response time is shorter when answer is correct.

4.2.9 Analysis of Intensity

The Maltese AAST is an adaptive speech test with the intensity of the stimulus words varying according to the listener's performance. Table 38 shows the mean intensity used in the test along other descriptive statistics.

Table 38

Descriptive statistics for Intensity (dB SPL) in Maltese AAST stimulus words

	N	Minimum	Maximum	Mean	SD
Intensity	44129	0	85	44.07	16.423

4.2.9.1 Analysis of Intensity according to age

An Independent Samples Kruskal-Wallis Test showed that there was a statistically significant difference in the distribution of intensity across the age categories ($\chi2$ (5) = 2386.482, p = 0.000). Pairwise comparison also shows that this difference is significant (p = 0.000) across every age group. The mean ranks table, Table 39 indicates that as age increases, the mean rank for intensity decreases.

Table 39

Mean Ranks of Intensity across age groups

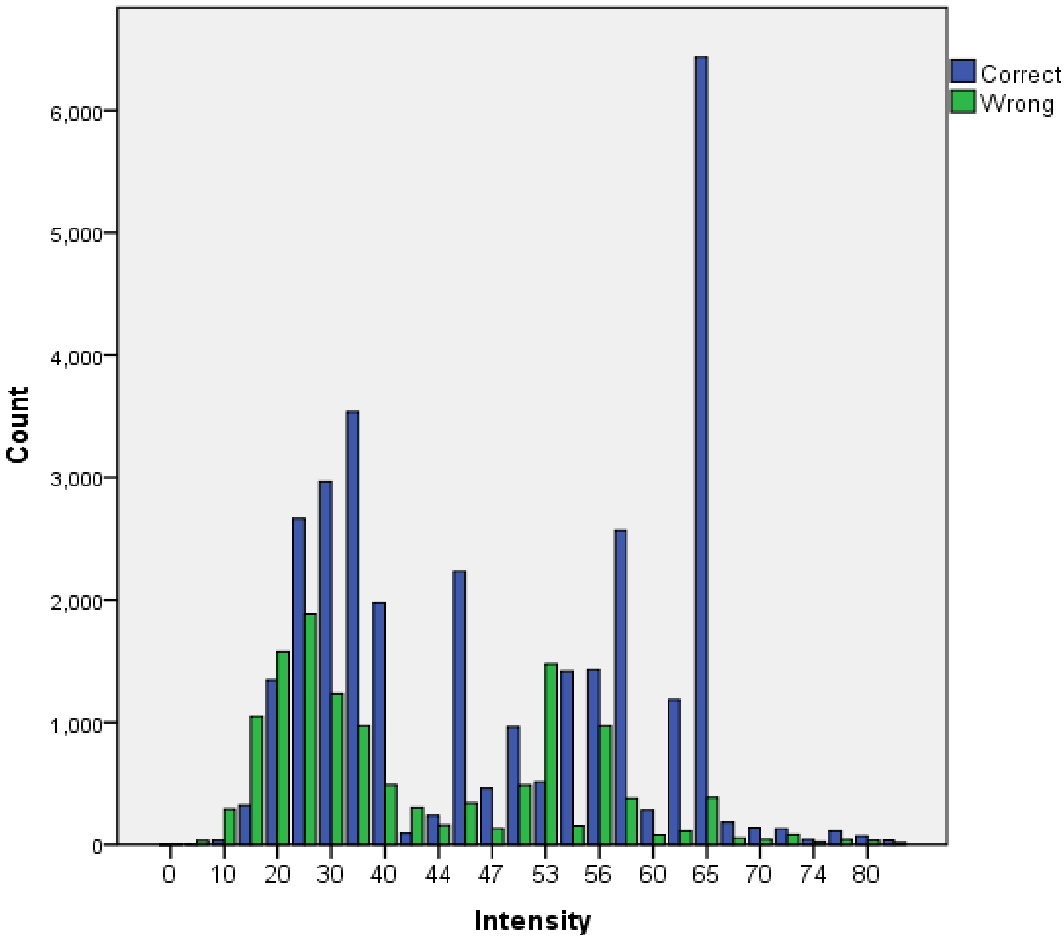
Age (years)	N	Mean Rank
4	7265	26981.39
5	7104	24165.42
6	6677	22587.03
7	9118	21422.57
10	6959	19197.95
Adults (18-30)	7006	18023.45

4.2.9.2 Analysis of Intensity according to Correct/Wrong answers

A Mann-Whitney U test showed that there was a significant difference (U =129,053,900.000, p = 0.000) between the intensity for correct answers when compared to the intensity for wrong answers. This is statistically significant (p = 0.000) across each age group. The median for correct answers was 24,336.84 compared to 16,489.78 for wrong answers suggesting that the intensity is higher when the answer is correct. This is clearly illustrated in Figure 28.

Figure 28

Number of Correct and Wrong answers according to Intensity level (dB SPL)



4.2.9.3 Correlation between Intensity and SRT

A Pearson product-moment correlation was run to determine the relationship between intensity and SRT. There was a moderate, negative correlation between intensity and SRT, which was statistically significant (r = -.384, n = 44129, p = .000). Table 40 shows that as intensity decreases, the SRT increases. When age is accounted for, similar results emerge. There is a negative low correlation in four-year olds, moderate negative correlation in 5, 6-year-olds and adults, and a strong negative correlation in 7- and 10-year-olds.

Table 40

Correlation between Intensity (dB SPL) and SRT scores according to age groups

		Intensity	SRT	
Intensity_4years	Pearson Correlation	1.000	-.279	Low negative correlation
	Sig. (2-tailed)		.000	
	N	7265	7265	
Intensity_5years	Pearson Correlation	1.000	-.400	Moderate negative correlation
	Sig. (2-tailed)		.000	
	N	7104	7104	
Intensity_6years	Pearson Correlation	1.000	-.493	Moderate negative correlation
	Sig. (2-tailed)		.000	
	N	6677	6677	
Intensity_7years	Pearson Correlation	1.000	-0.539	Strong negative correlation
	Sig. (2-tailed)		.000	
	N	8775	8775	
Intensity_10years	Pearson Correlation	1.000	-0.582	Strong negative correlation
	Sig. (2-tailed)		.000	
	N	6994	6994	
Intensity_Adults	Pearson Correlation	1.000	-.414	Moderate negative correlation
	Sig. (2-tailed)		.000	
	N	7006	7006	

4.2.10 Analysis of reversal points

A reversal point in AAST testing is the last threshold in a series of descending thresholds at which the stimulus is correct. During this study, the software was set to stop at 7 reversal points as evidenced in Figure 29. An average was taken for all 3 test settings, across each age group. Table 41 shows the reversal points for adults. Refer to Appendix H for detailed analysis for each age group. In adults, the threshold at reversal point seems to decrease with the number of reversals and then stabilise.

Figure 29

Example of 7 reversal points (dB SPL) on AAST on BELLS Software

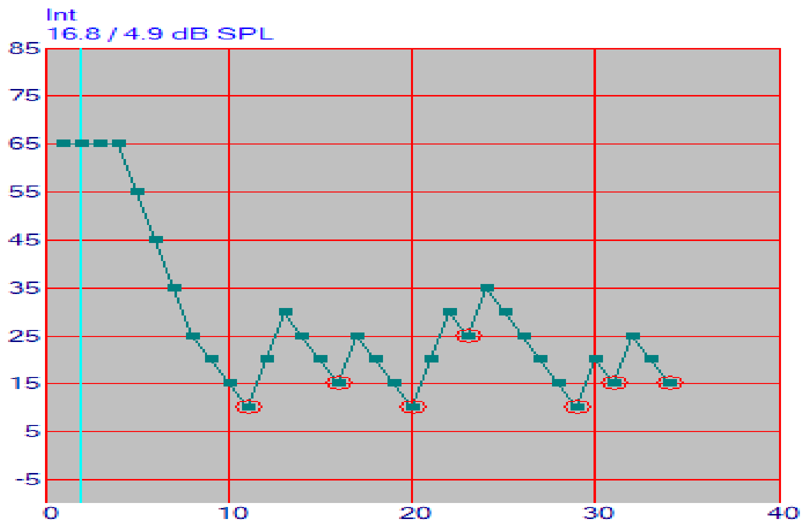


Table 41

Average of thresholds at 7 reversal points in Quiet, Noise and High frequency in adults

Reversal	Quite	Noise	High frequency
1	20.1	-16.7	29.4
2	20.1	-16.2	28.5
3	19.8	-16	28.5
4	19.6	-16	28.1
5	19.3	-16	27.9
6	19.3	-16	27.7
7	19.3	-16	27.8

Independent samples Kruskal-Wallis tests were used to determine whether the distribution of thresholds across the 7 reversal points is the same. As seen in Table 42, there is no statistically significant difference between reversal points across age groups in Quiet and High frequency settings. This means that 7 reversal points are more than enough to measure the SRT thresholds during AAST.

Table 42

Independent Samples Kruskal Wallis results for reversal points thresholds in Quiet, Noise and High frequency across the different age groups

		Chi-Square	df	*p* value
4 years	Quiet	2.949	6	.815
	Noise	39.527	6	.000
	High	3.384	6	.759
5 years	Quiet	2.657	6	.851
	Noise	36.351	6	.000
	High	.635	6	.996
6 years	Quiet	.120	6	1.000
	Noise	28.256	6	.000
	High	7.483	6	.279
7 years	Quiet	1.508	6	.959
	Noise	15.616	6	.016
	High	3.470	6	.748
10 years	Quiet	5.315	6	.504
	Noise	3.776	6	.707
	High	.571	6	.997
Adults	Quiet	3.114	6	.794
	Noise	56.038	6	.000
	High	.983	6	.986

There is, however, a significant difference in Noise across all age groups, except in 10-year-olds. Pairwise comparisons were carried out to investigate at which point the difference is statistically significant (See Appendix H). Table 43 is a summary of the findings confirming that on average, two or three reversal points are necessary for running AAST.

Table 43

Summary of pairwise comparisons results for reversal points thresholds in Noise across the different age groups

Age group	Reversal points needed
4 years	3
5 years	2
6 years	3
7 years	2
Adults	2

4.3 Conclusion

In summary, the results of this study confirm that the Maltese LEAQ and AAST versions have been found to be sensitive, quick, and reliable tests to check auditory development and speech recognition skills respectively in the Maltese speaking population under study. The findings will be discussed in more detail in the next chapter in light of previous studies in the area. Implications for practice will also be discussed.

5. DISCUSSION

This chapter will focus on the findings of this study. These are discussed in light of the research outcomes and how they relate to findings in the literature. The aims of this research project were to translate and validate the LittlEARS® Auditory Questionnaire in the Maltese language and to validate the Maltese language version of the Adaptive Auditory Speech Test (AAST). Both of these tools were developed to cater for the lack of normative tools available for the assessment of speech recognition in Maltese-speaking children and adults in the local population.

In this chapter, an interpretation of the results obtained from this research will be discussed in relation to the aims of the study and to previous research studies. The discussion will initially focus on the psychometric properties of the Maltese version of LEAQ in Section 5.1.1. The normative curve for the Maltese version is discussed and compared to other language versions in Section 5.1.2. The second part of the discussion focuses on the Maltese version of AAST. The norms of AAST in Quiet across the different age groups are discussed in Section 5.2.1. Section 5.2.2 addresses the norms of AAST in Noise, whilst Section 5.2.3 will focus on the norms of AAST in High frequency. A short comparison of AAST in Quiet, Noise and High frequency will be discussed in Section 5.2.4. Section 5.2.5 discusses results from the Confusion Matrix and Test-Retest Reliability. Correct answers are discussed in Section 5.2.6 whilst the effect of Response Time and Intensity are discussed in Sections 5.2.7 and 5.2.8 respectively. Reversal points are discussed last in Section 5.2.9. The discussion is brought to a close by giving a final thought on the combined use of subjective and objective measures for evaluating speech recognition.

5.1 LittlEARS® Auditory Questionnaire

5.1.1 Psychometric properties of Maltese LEAQ

One of the principal aims of this study was to adapt LEAQ for use with Maltese-speaking parents, caregivers and professionals. Two measures were included; the psychometric properties of the Maltese version of LEAQ and the generation of normative data for Maltese children involved in the questionnaire.

Translation of established questionnaires has often been the choice in populations whose language is not English. The challenge lies in adapting a tool in a culturally relevant manner whilst maintaining the meaning and intent of the original item. In this study, a back translation method was used to develop the Maltese version. This is similar to the Polish (Obrycka et al., 2009), Spanish (García Negro et al., 2016), Mandarin (Wang et al., 2013), Hebrew and Arabic (Geal-Dor et al., 2011) and Yoruba versions (Kayode & Adeyemo, 2018) of LEAQ. This method allowed for errors to be identified and improved the readability of the questionnaire by eventually developing two questionnaires, one for males, and one for females. The translation process was a result of multidisciplinary teamwork between translators, university lecturers and speech and language pathologists.

In order to evaluate the reliability and validity of the Maltese version of LEAQ, scale and item analysis were carried out. Results of the scale analysis showed that the Maltese version of LEAQ showed satisfactory age-dependency since a high correlation (0.90) between age of the children and total score was observed. The older the child, the higher the child's expected score. This provides evidence for the validity of the Maltese version of the LittlEARS® questionnaire. When compared to other language versions such as Mandarin (Wang et al., 2013), Yoruba (Kayode & Adeyemo, 2018) and Persian (Zarifian et al., 2019), one can note that the Maltese version shows one of the highest correlation coefficients, and has a very similar coefficient value to the original German version (0.91) (Coninx et al., 2009).

Scale analysis also showed high internal consistency. Responses from subjects were greatly consistent across the questionnaire items. The Cronbach's alpha coefficient value is 0.92 for the Maltese LEAQ and similarly 0.96 for the original German version (Coninx et al., 2009). This is also evident across other LEAQ versions shown in Table 7, which all show high internal consistency values higher than 0.90. This suggests that in Maltese and interlingually, LittlEARS® can reliably differentiate the degree of auditory development in children. This is especially so since hearing development predictors should not differ across children speaking different languages.

The split-half reliability coefficient for the Maltese version of LittlEARS® was 0.92 which indicates a high measuring accuracy of the questionnaire. The Maltese LEAQ obtained slightly higher scores than the original German version (0.88) (Coninx et al., 2009) and other languages such as Yoruba (0.70) (Kayode & Adeyemo, 2018) and Persian (0.73) (Zarifian et al., 2019). The Mandarin version also shows excellent reliability with a 0.91 reliability coefficient (Wang et al., 2013).

Lastly, scale analysis showed high predictive accuracy with a value of 0.92. This is very similar to the German (0.93) (Coninx et al., 2009), Turkish (0.91) (Koşaner et al., 2014), and Mandarin version (0.88) (Wang et al., 2013). The Persian version (Zarifian et al., 2019) has a higher predictive accuracy (0.96), whilst the Yoruba (Kayode & Adeyemo, 2018) has a low but satisfactory value (0.58). The high predictive accuracy of the Maltese version suggests that the dependent variable, in this case the total score on LEAQ, can be accurately predicted based on the independent variable, which is the age of the child. This has serious implications for the use of LEAQ in a clinical setting, whereby the expected scores of children at a certain age are compared to the actual scores of the child and clinical decisions are taken accordingly.

As regards item analysis, the results of this study showed that the index of difficulty is slightly higher in the Maltese version (0.65) when compared to the original German version (0.63) (Coninx et al., 2009). These findings are similar across the Mandarin (0.68) (Wang et al., 2013) and the Spanish version (0.64) (Spitzer & Zavala, 2011). A high difficulty index for an item indicates that it reflects early developed behaviours and thus less complex auditory skills. The items on the LEAQ become more difficult as the questionnaire progresses, with more complex items at the end of the questionnaire. This occurs as the auditory skill necessary becomes more advanced. As mentioned in the results section, items with a high index of difficulty were kept in the questionnaire in order to avoid zero-points-scores as they put less pressure on the parents who are filling out the questionnaire. The low discriminatory power of the initial questions is similar across language versions such as German (Coninx et al., 2009), Mandarin (Wang et al., 2013), Spanish (Spitzer & Zavala, 2011) and Yoruba (Kayode & Adeyemo, 2018). Culture may play a part, as whilst Question 14 has a low discriminatory power in the above languages, it has a moderate 0.61 in the Maltese version. Question 14 refers to whether a child can be calmed down or influenced by music when he is sad or moody. In the Maltese culture, it is very common for the parents to sing a nursery rhyme or select one from the mobile phone to calm down infants and toddlers. This coping mechanism has increased over the recent years due to advancements in mobile technology and could potentially account for the difference in discriminatory power in this population.

The correlation of item score to the child's age was investigated to check the items' suitability for measuring the age-dependency of behaviour. About one third of the LEAQ items showed a strong positive correlation with age ($r \geq 0.7$) confirming that parents report few auditory abilities at a young age and an increasing number of auditory skills as they get older. As also reported in Offei's study (2013), this study confirms that the score remains fairly the same after the age of 24 months in normal-hearing children (N=131). The results of this study show that the Maltese version of LEAQ reaches maximum values between the age of 24 and 36 months. Over 92% of children above 24 months of age score between 32 and 35, confirming that ceiling effects remain stable. This finding shows that the Maltese version of LEAQ might be an efficient tool for the screening of children above 24 months of age along with other tests which are used routinely in an audiology clinic or school setting for the assessment of young children. Further research in this area, however, is warranted in the local population.

In summary, by comparing the Maltese version with the original German version and other language versions, this research shows that the psychometric properties of the Maltese version of LEAQ are excellent and indicate high reliability and validity as a screening tool of auditory behaviour in children less than 2 years of age.

5.1.2 Normative values of Maltese LEAQ

Research Question 1: Are the norm curves of the Maltese version of the LittlEARS® Auditory Questionnaire comparable to the German norm curve?

Normative data was generated from the total scores of the participants and their age and visually displayed as a norm curve. The average score for a particular child's age provided the expected value, whilst the lower limit of the 95% confidence interval provided the minimum values. The regression equation for the Maltese sample is $y= -0.03\ x^2 + 2.02x + 5.07$, whilst the regression equation of the German data is $y = -0.038x^2 + 2.22x + 2.07$. The coefficient of x and x^2 are very similar explaining why the two curves are almost parallel. The constant terms (5.07 and 2.07) differ by 3, implying that the Maltese children are scoring 3 points higher, on average, than the German data. The percentage of explained variance was 86% for the original German version and 82% for the Maltese LEAQ. This means that age is slightly more predictive of the total score in the German version than for the Maltese one. These slight differences in statistics could be due to the sample composition and mode of administration used in this research study. Overall, the original norm curve developed in German is very similar to the norm curve developed in this research study in the Maltese language.

Research Question 2: Are the norm curves of the Maltese version of the LittlEARS® Auditory Questionnaire comparable to other languages?

Table 44 shows the regression equation of several language versions. One can note that the coefficients are very similar across most of the languages, especially between the German, Maltese, Mandarin, and the multilingual study by Coninx (2009). Similarly, the constants of the Maltese norm curve differ very slightly (5.07 and 3.47) confirming how close the Maltese norm curve is to the 15 other languages validated by Coninx et al, (2009), when compared to other language versions.

Table 44

Comparison of the regression equations of LEAQ norm curves across language versions

Language	Regression Equation
Maltese	$y= -0.03 x^2 + 2.02x + 5.07$
German	$y= -0.038x^2 + 2.22x + 2.07$
15 languages (Coninx, 2009)	$y= -0.038x^2 + 2.163x + 3.470$
Mandarin	$y= -0.038x^2 + 2.23x + 1.21$
Polish	$y=-0.028x^2 + 1.98x – 4.85$
Spanish	$y= -0.052x^2 + 2.69x - 0.72$
Yoruba	$y= -0.081x^2 + 3.303x + 0.648$

A more noticeable difference is found between variance coefficients across other language versions. Whilst similar variance was obtained in languages such as Polish (83%), Spanish-USA (81%), Spanish (79%) and Persian (80%), larger differences from the original German version were noticed in other languages such as Mandarin (73%), Turkish (74%), Yoruba (75%), Hebrew (85.7%) and Arabic (72.7%). Overall, one can conclude that the Maltese norm curve is very similar to the 15 other languages validated by Coninx et al., (2009), German and Mandarin.

In conclusion, the results indicated that the Maltese version of LEAQ is a valid and reliable outcome tool in the Maltese-speaking population. This study supports the use of LEAQ for taking informed decisions in a clinical or educational setting as it makes valid inferences about the child’s auditory development in the first 2 years of life. This is due to the excellent psychometric properties of the Maltese version, including the high correlation between age and score. Responses that fall below the minimum and expected values would alert the professionals involved with the child (such as paediatricians and speech and language therapists) to be alert and refer for an audiological evaluation accordingly. Most importantly, LEAQ has the potential to fill in an important gap in the screening and diagnosis of hearing-impaired children between birth and school age. In Malta, developmental assessment for babies is carried out at 3 routine visits at 6 weeks, 8 months, and 18 months respectively. These visits are done at the Well Baby Clinics which are available at the community level, making it a very accessible service. At these visits, clinical examinations are carried out to evaluate whether the child has reached certain developmental milestones. Thus, including a hearing screen at one of these stages would potentially aid in identifying children with hearing loss who were not identified at birth. The Maltese version of LEAQ would ideally be carried out at the 18 months visit. At 8 months of age, a limited number of ‘yes’ responses may be scored on LEAQ, which would limit its use as a screening instrument.

The Well Baby service is available also for babies born in a private hospital, thus enabling a larger number of children to be screened.

Screening post UNHS is indeed becoming an essential part in the identification and management of hearing loss, and this is only possible through reliable tools such as LEAQ. It is crucial in the identification of hearing loss that is late-onset, acquired, or not detected in newborns. It is known that early identification supports speech and language development and literacy skills (Korver et al., 2010; Nikolopoulos, 2015).

Future research is also recommended in relation to the use of LEAQ in monitoring children's progress with hearing aids and cochlear implants and in planning rehabilitation programmes.

5.2 Maltese version of the Adaptive Auditory Speech Test

AAST is a computer-based speech audiometry test that can be used as a diagnostic tool to adaptively determine the SRT, and in Noise to determine the SNR accordingly. The purpose of this study was to develop and provide normative data for AAST in the Maltese population. The aims were to determine the norms in Quiet, Noise and High frequency, in Maltese-speaking adults and children aged 4 years and older. The sample included 248 Maltese-speaking children and adults.

5.2.1 AAST normative values in Quiet

Research Question 3: What are the norms of AAST in Quiet for Maltese adults and children aged from 4 to 10- years old?

The SRT in Quiet decreases significantly between 4-year-olds and 10-year-olds. This means that older children perform better than younger children. The mean SRT in 4-year-olds is 32.3 dB SPL, improving significantly to 28 dB SPL in 5-year-olds, 25.3 dB SPL in 6-year-olds and 23.4 dB SPL in 7-year-olds. No significant difference (p = .0916) was reported between SRT scores in Quiet in 10-year-olds (19.1 dB SPL) and adults (19.2 dB SPL) showing that Maltese children at age 10 years achieve the same thresholds as in adults. This suggests that speech recognition skills mature as children grow older and stabilise at around 10 years of age. The correlation between the SRTs and age in the children groups were estimated by a slope value of 2.2 dB per year in Quiet.

Mohammed (2010) reported similar values in 5–7-year-olds in Quiet (26.6 dB SPL) in the Arabic version. On the other hand, Maltese thresholds are noted to be slightly better than the Vietnamese norm values (Nguyen, 2017), across all ages; 21–30-year-old group (29.4 dB SPL), 15–20-year-old group (30 dB SPL), 8-year-olds (31 dB SPL), 6-year-olds (31.8 dB SPL) and 4-year-olds (37.2 dB SPL). Nguyen attributed these high thresholds to the high level of background noise during testing.

An age dependent norm threshold difference was observed in the Maltese version of AAST. There is a mean 13dB difference between 4-year-old children and 10-year-old children in AAST in Quiet. Children aged 10 years achieved average speech thresholds that were comparable to adult thresholds. This trend is very similar across other AAST language versions (as previously illustrated in Figure 20). Coninx (2005, 2008) reported a 10dB difference between younger and older children in the German version, very similar to the Polish one with an 11dB difference. Offei (2013) and Nguyen (2017) on the other hand, reported a slightly less difference of 7dB and 8dB in the Ghanaian and Vietnamese version accordingly. Based on these findings, it can be confirmed that listener's age and their SRT in AAST are also interdependent in the Maltese AAST.

In the Maltese version of AAST, the steepness of the slope was 6.6%/dB in Quiet. Offei (2013) reported a slope of 10.2%/dB in Quiet for the Ghanian version, whilst Nguyen (2017) reported a slope of 8.2 %/dB. In comparison to other speech tests such as the Oldenburger Kinder Satztest (Wagener & Kollmeier, 2005), which had slopes of 6–8%/dB in

Quiet, slight differences also emerge. These differences could be attributed to the sample composition in the population under study.

Lastly, it is vital to point out that a weak to moderate correlation was observed between SRT values in Quiet and the participant's PTA average. This means that an increase in the participant's PTA average was only weakly to moderately correlated to an increase in SRT levels in Quiet, confirming that the 2 tests measure different aspects of speech recognition and thus, both need to be included in the assessment process.

5.2.2 AAST normative values in Noise

Research Question 4: What are the norms of AAST in Noise for Maltese adults and children aged from 4 to 10 years old?

The features of SRTs in Noise were relatively similar to those in Quiet. The results for the AAST in Noise showed that the mean SRTs obtained by the younger children decreases significantly between 4-year-olds and adults. While 4-year-olds scored an average of -12.6 dB SNR, 5- and 6-year-olds scored slightly better with a mean of -13.6 dB SNR and -14.5 dB SNR respectively. 7-year-olds scored significantly higher with an average of -15 dB SNR. The mean SRT of 10-year-olds was -15.6 dB SNR, whilst the adults performed best at an average of -16.3dB SNR. The correlation between the SRTs and age in the children groups were estimated by a slope value of 0.5 dB per year in Noise. This close correlation was also reported by Nguyen (2017) with a slope value of roughly -1 dB per year.

As regards psychometric function, the Maltese version had a slope of 14.3%/dB in Noise, very similar to Vietnamese (Nguyen, 2017) with 8.4%/dB. With respect to the German AAST, (Coninx, 2005, 2008), the slope was 14%/dB in Noise, which is very close to the Oldenburger Kinder Satztest (Wagener & Kollmeier, 2005) which had slopes of 12–14%/dB. This suggests that a small increase in SNR in the German version of AAST would lead to a large increase in intelligibility. Since the slope is less steep in the Maltese and Vietnamese version, the same SNR improvement would lead to a smaller perceptual improvement in speech intelligibility.

In comparison to Mohammed's study (2010), Arabic SRT thresholds in Noise were somewhat alike those of the Maltese version, with 5-year-olds having an average speech in Noise threshold of -10.8 dB SNR, 6-year-olds having a mean of -11.53 dB SNR and 7-year-olds with a mean of -11.95 dB SNR. Similarly, Nguyen reported 4-year-olds having poor mean speech threshold values between -9.5 and -6.5 dB SNR. The mean SRT of adults in Vietnamese was approximately -14 dB SNR, which is also slightly below the Maltese mean SRT in Noise. Overall, one can conclude that Maltese children and adults scored better than Arabic and Vietnamese participants in Noise. This difference could be due to the sample of the populations in the respective studies and the high levels of background noise reported by Nguyen (2017).

5.2.3 AAST normative values in High frequency

Research Question 5: What are the norms of AAST in High frequency for Maltese adults and children aged from 4 to 10 years old?

The speech recognition thresholds in High frequency follow the same patterns as those in the Quiet and Noise setting, with thresholds significantly decreasing as the age of the children increases. The mean SRT of 4-year-olds was 41.5 dB SPL, decreasing significantly to 35.8 dB SPL in 5-year-olds, and down to 33.2 dB SPL in 6-year-olds. By 7 years of age the mean SRT in High frequency goes down to 30.5 dB SPL and further down to 25.8 dB SPL in 10-year-olds. Adults perform as well as 10-year-olds in the Maltese High frequency version with a mean SRT of 27.6 dB SPL. This is similar to results obtained in the Quiet setting. In addition, the correlation between the SRTs and age in the children groups is also very similar; with a value of 2.2 dB per year in Quiet and 2.6 dB in High frequency. In addition, a moderate to strong correlation is reported between SRT values in Quiet and High frequencies across age groups. It can also be pointed out that there is an average difference of about 8dB SPL between SRT values in Quiet and those in High frequency, confirming that the High frequency (whispered) version is more demanding on the listener.

The lack of vocal folds vibration is the main physical feature and the most significant acoustic characteristic of whispered speech. Whispering affects only voiced sounds, such as vowels, which are thus produced by forcing air through a constricted opening between the vocal folds in the larynx. It generally tends to be higher in frequency than the corresponding voiced speech. Vestergaard and Patterson (2009) assert that whispering removes the natural temporal fine structure of voiced speech and thus may affect the redundancy of speech information. This would explain the consistently higher thresholds obtained in this study, across all age groups.

5.2.4 Comparison of AAST in Quiet, Noise and High frequency

Some conclusions can be drawn on the speech recognition performance of Maltese listeners on the AAST. The results of this study indicate that the SRT values are age dependent as a significant improvement in threshold is observed as children grow older. This was evident across the 3 test settings: Quiet, Noise and High frequency. A 13dB difference was noted between 4-year-old children and 10-year-old children in AAST in Quiet. This age-related difference may be due to the limited attention of younger children as speech perception relies on several cognitive and linguistic factors, including selective attention, short-term memory and lexical knowledge which improve as children get older. Overall, the children showed an interest in the test since it was displayed on a tablet pc, confirming that AAST is appropriate for use in young children.

As stated earlier, the 10-year-olds obtained a good SRT, which was comparable to that of adults in both the Quiet and High frequency versions suggesting that speech recognition skills are mature in normal-hearing older children and are comparable to those of normal-hearing adults.

5.2.5 Confusion Matrix and Test-Retest Reliability

This speech test was designed on the same procedures used in constructing other language versions such as AASTs in German, Polish, Ghanaian and Vietnamese. The confusion matrices of the Maltese AAST also show that there is minimal confusion between the 6 stimulus words chosen. There was no word that the participants confused more than 20% of the time. The most confused stimulus overall was 'glasses', mostly confused with 'presents' and vice versa. Nonetheless, the confusion was minimal, and not significant, confirming that the 6 words chosen when constructing the test are homogeneously audible for speech testing in the Maltese population. This also means that the children's scores were not random and that the test is validly assessing speech recognition thresholds in children and adults.

As regards reliability, test-retest reliability of the Maltese version of AAST was also confirmed on a small sample of participants. There was no significant difference between the initial and second retest in the Quiet (p = .656), Noise (p = .549) or High frequency setting (p = .573). This ensures that the measurements obtained in one sitting were both representative and stable over time preventing any age-related changes in performance or learning effects. Previous studies conducted by Mohammed (2010) and Nguyen (2017) also show that there are no learning effects in the Arabic and Vietnamese AAST accordingly. Offei (2013) on the other hand, reported some learning effects in children but not in adults. Nguyen (2017), however, stated that although there was no statistically significant difference, the improvements in SRTs (1-2.5 dB) may affect the clinical findings to some degree.

5.2.6 Correct answers

The findings in this study show that as age increases, the percentage of correct answers also increases significantly. In addition, it could be noted that in children more correct answers were scored in Quiet, followed by High frequency and least in Noise. Adults, however, scored as well in Quiet as in the other two settings. The above findings suggest that speech recognition abilities of children keep on developing throughout childhood and their ability to decode degraded signals such as speech in Noise and High frequency improves accordingly with age.

5.2.7 Response Time

Response time is also an interesting factor to consider in the analysis of automatic adaptive speech tests. Results from this study confirm that response time is also dependent on the child's age. A statistically significant difference was observed across all age categories (p = 0.000), except for 5- and 6-year-olds. As children get older, response time decreases, possibly in relation to the maturity of the attention and concentration skills which are still developing in very young children.

The effect of the test type (Quiet, Noise or High frequency) was also evaluated in this study. It is interesting to note that while there was no statistically significant difference in response time between the different test settings in 4-, 5- and 6-year-olds, a significant difference was observed in older children and adults. In 7-year-olds and 10-year-olds, response time was significantly longest in Noise and shortest in High frequency. In adults, the longest response time was also in Noise, followed by High frequency and shortest in Quiet. Overall, it can be concluded that as children grow older, listening in noise remains a challenge, as evidenced by the longer response time observed in this study. This finding supports the notion that speech in noise tests are to be included in the assessment batteries as they cannot be predicted from scores in quiet. It also highlights the importance of using response time in speech tasks as a measure of the cognitive load in speech recognition. As mentioned earlier, similar findings have been reported across studies (Meister et al., 2018; Pals et al., 2015; Pisoni et al., 2011; Prodi & Visentin, 2019). As listening conditions become more degraded, listening effort also increases as evidenced by response time increase.

5.2.8 Intensity

Since the Maltese AAST is an adaptive speech test, the intensity of the stimulus words varies according to the listener's performance. The average intensity level used for the participants in the study was significantly lower as the age of the participant increased. This finding is also probably related to the short attention span of very young children which improves as they get older. Additionally, it was also observed that correct answers had a significantly higher intensity level than wrong answers. ($p = 0.000$). A higher intensity level would increase audibility and the signal-to noise ratio, thus increasing the chance of correctly identifying the item being presented with. The relationship between intensity and SRT was also evaluated in this study, confirming a significant moderate, negative correlation ($r = -.384$). This means that as intensity increases, the SRT decreases. When age is accounted for, a clearer picture emerges. Whilst there is a negative low correlation in 4-year-olds, as children grow older the correlation improves. A moderate negative correlation was reported in 5, 6-year-olds and adults and a strong negative correlation was reported in 7- and 10-year-olds. This clearly reflects the age dependent thresholds obtained in this study.

5.2.9 Reversal Points

An estimate of the participants' thresholds was calculated by averaging the levels at the reversal points. A reversal point in AAST testing is the last threshold in a series of descending thresholds at which the stimulus is correct. During this study, the software was set to automatically stop at 7 reversal points. In general, the accuracy and reliability of the threshold estimate may be improved by obtaining a larger number of reversals. However, time may be a limiting factor when testing children as they may become restless or inattentive. A child with a short attention span may respond inconsistently and only at supra-threshold levels, leading to elevated SRT levels. Children may be unable to complete the full number of reversals and thus the relationship between SRT and reversal points was evaluated in this study across different age groups and test settings (Quiet, Noise and High frequency).

In this study, there was no statistically significant difference between reversal points across any age group in Quiet and High frequency settings. This means that 7 reversal points are more than enough to measure the SRT thresholds during AAST. In Noise, a significant difference was observed across all age groups, except in 10-year-olds. Detailed analysis showed that on average 2 or 3 reversal points were necessary to maintain stable AAST thresholds across age groups in Noise. This is an important finding for clinicians who would like to use the Maltese version of AAST for screening purposes as it enables them to screen more children in a shorter time and enable reliable results in children who have a short attention span.

In conclusion, the findings of this study confirm that the Maltese version of AAST is a valid and reliable adaptive speech test that may be used for Maltese-speaking children and adults alike. The Maltese version of AAST has the potential to be used as a school entry screening tool in Maltese speaking school age children, thereby creating another point in time where children with acquired or late onset hearing loss may be identified. School entry hearing screening would have a small but important role in early identification.

Ultimately, understanding and evaluating the development of speech recognition benefits both the audiological professionals and the individuals with hearing loss. The results of the study suggest that collecting normative data from questionnaires such as LEAQ and adaptive speech tests such as AAST can be helpful in quantifying speech recognition in

Maltese speaking infants, children, and adults. They can serve as screening and assessment tools for the early identification of hearing loss in the Maltese population, potentially filling in the gap between the diagnosis/screening between birth and school. Especially for young children, there are very few subjective methods that can be used reliably and at the same time are appropriate for children. The findings from this study serve as an initial step in exploring subjective and objective measures in an attempt to better characterise speech perception in the Maltese Islands through the collection of normative data. Ultimately, normative data would enable comparison of normal-hearing individuals to those of hearing-impaired for better identification and management.

6. CONCLUSION

The data from this study is bound to make a substantial contribution in local clinical and educational settings. The developed tools are essential for screening and assessment purposes in the Maltese population due to the lack of language specific tools in the Maltese language. The translation and validation of the Maltese version of a widely used questionnaire, the LEAQ, and the construction and norming of the Maltese AAST on a representative sample of normal hearing Maltese-speaking children and adults has been the primary goal and achievement in this study.

Findings of this study support the use of the Maltese version of the LEAQ as a valid and reliable tool to assess the development of auditory behaviour of Maltese children less than 2 years of age. Normative data was generated from the total scores of the participants and their age in months. Together with the calculated expected and minimum values, a child's score can serve as a basis for an informed decision about the child's auditory progress or lack thereof. The Maltese LEAQ can be used in routine check-ups by a diverse range of professionals such as clinical and educational audiologists, speech and language pathologists, school teachers, teachers of the deaf and paediatricians. Most importantly, in Malta, LEAQ could be the basis of a post-UNHS screening carried out at the 18th month developmental check-up at the Well Baby Clinic. This will help in identifying children who have passed UNHS but are at risk of hearing loss, children with late onset or progressive hearing loss and any other child who would have been lost to follow up.

The development of the Maltese AAST is particularly important because of the lack of tools for measuring speech perception skills in the Maltese language, as well as the paucity of validation studies in this population of children. The Maltese AAST may be used as a diagnostic tool to adaptively determine the SRT in Quiet and High frequency, and in Noise to determine the SNR accordingly. The results of this study confirm an age dependent norm threshold, indicating that the SRT values are age dependent, with a significant improvement in threshold being observed as children grow older. This was evident across the 3 test settings: Quiet, Noise and High frequency. Similar to other AAST language versions, an approximate difference of 10dB was also noted between 4-year-old children and 10-year-old children in AAST in Quiet. In addition, 10-year-olds obtained a good SRT, which was comparable to that of adults in both the Quiet and High frequency versions suggesting that speech recognition skills are mature in normal-hearing older children and are comparable to those of normal-hearing adults.

The Maltese AAST has important implications for screening purposes in school-age children in the Maltese population. The findings in this study confirm that the Maltese version is a simple and quick adaptive speech test appropriate for children as young as 4 years of age, making it ideal as a school-entry hearing screening test. Since it is a closed test, the influence of vocabulary and cognition is limited. Learning effects were not observed, and since test scores are automated, human interpretation is not needed for analysis. Therefore, it can be confirmed that the test is both reliable and valid.

Besides, normative data across several age groups was collected. This data would be essential in carrying out a school-hearing screening to identify which children deviate from the norm and thus need further audiological evaluation.

6.1 Limitations of this study

A potential weakness of the data collection in LEAQ is related to self-selection bias. This is related to the fact that parents were allowed to decide whether or not they wanted to participate in the study. Since the total number of participants was high (N = 398) and representative of the Maltese population, the risk for selection bias was minimised. As regards AAST, the main limitation lies in the limited follow-up that was available to some children who had very high thresholds at the end of data collection due to Covid-19. Due to the closure of the schools, and limited clinics available at the hospital for testing, some of these children could not be followed up. Another limitation is related to the very young age of the children in the population under study. This may have added variability to the results due to their limited attention span. It is understood that this could have led to increased SRT thresholds in some cases.

6.2 Future research

Based on the findings, limitations and the scope of this study, the following is being recommended for future investigation.

6.2.1 LEAQ

A pilot project on the use of LEAQ as a hearing-screening tool beyond UNHS at the Well Baby Clinics is recommended. This will help identify any issues that can be tackled prior to starting a nationwide screening programme.

Future work will also investigate the use of the Maltese LEAQ as part of a routine outcome evaluation tool for infants and children with permanent hearing loss. The auditory development of children wearing hearing aids and cochlear implants is an important aspect in the rehabilitation process. It is crucial to gain an understanding of the variability in progress of children with sensorineural loss. By assessing auditory development over time, realistic expectations can be drawn up based on the child's age and scores. This will allow for an evaluation of the impact of degree of hearing loss which would assist professionals in the rehabilitation process.

6.2.2 AAST

The Maltese AAST provides objective information on a child's speech perception development, thus enabling comparisons between children of varying ages. The findings show that it is a reliable and valid screening tool which will improve the quality of speech audiometry in Malta. A pilot project of the school-hearing screening is recommended. In addition, future studies may investigate the use of AAST as an outcome measure in hearing aid and cochlear implant patients in order to track progress according to age, degree of hearing loss and time since implantation or aiding, amongst others.

Ultimately, it is hoped that this study will lead to better understanding of the development of speech perception in the Maltese population and serve as a catalyst in implementing post UNHS and school-age screening.

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APPENDICES

Appendix A: Approval of University Research Ethics Committee of the University of Malta

L-Università ta' Malta

University Research Ethics Committee (UREC)

University of Malta,
Msida MSD 2080, Malta

urec@um.edu.mt

www.um.edu.mt/urec

26th April 2018

Ms Pauline Miggiani
"Manjoe"
Triq Carmelo Penza
Xghajra, Zabbar

Dear Ms Miggiani,

The University Research Ethics Committee is pleased to inform you that, based on the information contained in your proposal, your research entitled "**Measuring the outcomes of early intervention in young children with hearing impairment: A key issue in rehabilitation and screening measures" (Ref. No. UREC-DP1801016EXT)** has been found to be consistent with the University of Malta Research Code of Practice. You may therefore commence your research.

Yours sincerely,

____

Dr Leonie Baldacchino, Ph.D. (Warw.)
Chairperson's Delegate, UREC-DP
University of Malta

Appendix B: Permission from the Data Protection Officer, CEO and Head Consultant of ENT and Audiology at Mater Dei Hospital

Nursing Officer

ENT OP

Dear Mr Marco Curmi,

I am an Audiologist currently employed at ENT Outpatients at Mater Dei Hospital reading for a Phd in Rehabilitation Sciences at the University of Cologne, Germany. As part of this course I will be carrying out a research study in Maltese individuals to develop and norm a battery of tests to be used in clinics when examining toddlers and young children. These tests will be carried out at school or at ENT Outpatients at Mater Dei Hospital.

The first part of the study involves children under 3 years of age whose parents will be encouraged to complete a hearing questionnaire, a Maltese version of LittlEARS, which was initially designed to evaluate the benefit of cochlear implants. Otoacustic Emissions (OAEs) will also be carried out on this population.

In the second part of this study, children over 3 years and adults will be asked to participate in two tests. In the adaptive speech audiometry test, they will be asked to point to a picture corresponding to the word spoken through headphones to determine the speech reception threshold (SRT). This test will be done in quite and in noise. This test will be followed by pure tone audiometry.

These tests will be carried out by the undersigned qualified audiologist. Please note that all the data gathered and any information that may reveal the participants' identity will be kept confidential and will not be disclosed at any point in the study. The data will be used only for scientific purposes.

I would therefore like to request permission to carry out the said assessments on this group of participants at ENT Outpatients, Audiology. If you agree, kindly sign overleaf. Alternatively kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission to carry out the mentioned study at ENT Outpatients, Mater Dei Hospital.

Thank you in anticipation.

Regards,

Pauline Miggiani

Phd Student
Senior Allied Health Professional (Audiology)
pauline.miggiani@gov.mt

Prof. Frans Coninx

Project Supervisor
f.coninx@ifap.info

Approval form

I hereby acknowledge that I have read the letter attached and I give consent to Ms Pauline Miggiani to carry on with her research at ENT Outpatients. I know that confidentiality will be ensured and that letters will be delivered to the parents via snail mail by Mater Dei staff.

Approved by:

Mr. Marco Curmi
Charge Nurse
ENT Outpatients Unit
Mater Dei Hospital

Print your name and title here	Signature	15/3/18 Date

Dear Mr Said,

I am an Audiologist currently employed at ENT Outpatients at Mater Dei Hospital reading for a Phd in Rehabilitation Sciences at the University of Cologne, Germany. As part of this course I will be carrying out a research study in Maltese individuals to develop and norm a battery of tests to be used in clinics when examining toddlers and young children. These tests will be carried out at school or at ENT Outpatients at Mater Dei Hospital.

The first part of the study involves children under 3 years of age whose parents will be encouraged to complete a hearing questionnaire, a Maltese version of LittlEARS, which was initially designed to evaluate the benefit of cochlear implants. Otoacustic Emissions (OAEs) will also be carried out on this population.

In the second part of this study, children over 3 years and adults will be asked to participate in two tests. In the adaptive speech audiometry test, they will be asked to point to a picture corresponding to the word spoken through headphones to determine the speech reception threshold (SRT). This test will be done in quite and in noise. This test will be followed by pure tone audiometry.

These tests will be carried out by the undersigned qualified audiologist. Please note that all the data gathered and any information that may reveal the participants' identity will be kept confidential and will not be disclosed at any point in the study. The data will be used only for scientific purposes.

I would therefore like to request permission to carry out the said assessments on this group of participants at ENT Outpatients, Audiology. If you agree, kindly sign overleaf. Alternatively kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission to carry out the mentioned study at ENT Outpatients, Mater Dei Hospital.

Thank you in anticipation.

Regards,

Pauline Miggiani

Phd Student
Senior Allied Health Professional (Audiology)
pauline.miggiani@gov.mt

Prof. Frans Coninx

Project Supervisor

Approval form

I hereby acknowledge that I have read the letter attached and I give consent to Ms Pauline Miggiani to carry on with her research at ENT Outpatients. I know that confidentiality will be ensured and that letters will be delivered to the parents via snail mail by Mater Dei staff.

Approved by:

	Mr. Mario Said *Consultant & Head of Otolaryngology Services*	15/3/18
Print your name and title here	Signature	Date

RE: Re Phd Research study Audiology

Falzon Ivan at Health-MDH <ivan.falzon@gov.mt>

Thu 11/01/2018 16:10

To: Miggiani Pauline at Health-MDH <pauline.miggiani@gov.mt>;

Proceed then

Ivan Falzon
Chief Executive Officer | TeaMDH

SPTAR MATER DEI

T +356 2545 4102
M +356 9995 0393
E ivan.falzon@gov.mt

Mater Dei Hospital, Triq tal-Qroqq, Msida, Malta MSD 2090 | Tel +356 2545 0000 | [www.materdeihospital.org.mt]www.careandcure.gov.mt

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From: Miggiani Pauline at Health-MDH
Sent: Thursday, 11 January 2018 12:18
To: Falzon Ivan at Health-MDH
Subject: RE: Re Phd Research study Audiology

Good morning,

Thanks for your reply. I do have both endorsements.

Could you kindly confirm that I can proceed?

The DPO officers specifically said I do need your endorsement.

Dear Ms Miggiani
On the basis of the documentation you submitted, from the MDH data protection point of view you have been cleared to proceed with your study provided that you obtain approval from MDH CEO and the University Ethics Committee.
Please contact Ms. Nadine Buhagiar on 2545 5334 or Ms. Graziella Aquilina on 2545 5346 to present a copy of your approvals and fill in the appropriate Data Protection Form.
Remember that in no way should you retain any personal details you obtain from your research and this should be destroyed at the end of your study.
All medical records are to be viewed at the Medical Records Department MDH.
You are requested to submit a copy of your findings to this office at the end of your study.
Regards

Sharon Young
Data Protection Officer

Kind regards,

Pauline

From: Falzon Ivan at Health-MDH
Sent: Tuesday, 09 January 2018 18:26
To: Miggiani Pauline at Health-MDH
Subject: RE: Re Phd Research study Audiology

Dear Pauline,

Please get the endorsement for this from Mr Said and the Charge Nurse for OP/ENT.

Regards,
Ivan

Ivan Falzon
Chief Executive Officer | TeaMDH

SPTAR MATER DEI

T +356 2545 4102
M +356 9995 0393
E ivan.falzon@gov.mt

Mater Dei Hospital, Triq tal-Qroqq, Msida, Malta MSD 2090 | Tel +356 2545 0000 | [www.materdeihospital.org.mt]www.careandcure.gov.mt

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From: Miggiani Pauline at Health-MDH
Sent: Friday, 05 January 2018 13:38
To: Falzon Ivan at Health-MDH
Subject: Re Phd Research study Audiology

CEO
Mater Dei Hospital

Dear Mr Ivan Falzon,

I am an Audiologist currently employed at ENT Outpatients at Mater Dei Hospital reading for a Phd in Rehabilitation Sciences at the University of Cologne, Germany. As part of this course I will be carrying out a research study in Maltese individuals to develop and norm a battery of tests to be used in clinics when examining toddlers and young children. These tests will be carried out at school or at ENT Outpatients at Mater Dei Hospital.

The first part of the study involves children under 3 years of age whose parents will be encouraged to complete a hearing questionnaire, a Maltese version of LittlEARS, which was initially designed to evaluate the benefit of cochlear implants. Otoacustic Emissions (OAEs) will also be carried out on this population.

In the second part of this study, children over 3 years and adults will be asked to participate in two tests. In the adaptive speech audiometry test, they will be asked to point to a picture corresponding to the word spoken through headphones to determine the speech reception threshold (SRT). This test will be done in quite and in noise. This test will be followed by pure tone audiometry.

These tests will be carried out by the undersigned qualified audiologist. Please note that all the data gathered and any information that may reveal the participants' identity will be kept confidential and will not be disclosed at any point in the study. The data will be used only for scientific purposes.

I would therefore like to request permission to obtain access to these subjects and carry out the said assessments on this group of participants at ENT Outpatients, Audiology. If you agree, kindly reply to this email. Alternatively kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission to carry out the mentioned study at ENT Outpatients, Mater Dei Hospital.

Thank you in anticipation.

Regards,

Pauline Miggiani
Phd Student
Senior Allied Health Professional (Audiology)
pauline.miggiani@gov.mt

Prof. Frans Coninx
Project Supervisor

Pauline Miggiani
Bsc (Hons) Communication Therapy (Melit.)
Msc Audiology (Melit.)
Senior Allied Health Professional
ENT/OP

Appendix C: Permission from Ministry of Education and Secretariat for Catholic Education

Segretarjat għall-Edukazzjoni Nisranija
16, Il-Mall, Furjana FRN 1472
Num. ta' Tel. 27790060
Num. Tal-Fax 27790078

Secretariat for Catholic Education,
16, The Mall, Floriana FRN 1472
Tel. No. 27790060
Fax No. 27790078

The Head
St Theresa School, Kercem
St Monica School, B'Karara (KG), (JR)
St Joan Antide, Gudja (KG), (JR)

13th August 2019

Ms Miggiani Pauline, currently reading for a Ph.D. in Rehabilitation Sciences at the University of Cologne - German, requests permission to conduct an audiological test with children aged 3 years and above at the mentioned schools.

The Secretariat for Catholic Education finds no objection for Ms Miggiani Pauline, to carry out the stated exercise subject to adhering to the policies and directives of the schools concerned.

Rev Dr. Charles Mallia
Delegate for Catholic Education

DIPARTIMENT GHALL-KURRIKULU, RIĊERKA,
INNOVAZZJONI U TAGHLIM TUL IL-HAJJA
FLORIANA FRN 1810

DEPARTMENT FOR CURRICULUM, RESEARCH,
INNOVATION AND LIFELONG LEARNING
FLORIANA FRN 1810

Directorate for Research, Lifelong Learning and Employability

Tel: 25982265 **researchandinnovation@ilearn.edu.mt**

PERMISSION TO CONDUCT RESEARCH STUDY

Date: 18th January 2018

Ref: RI2018/003

To: **Head of School**
From: **Assistant Director (Research and Innovation)**

Title of Research Study: Measuring the Outcomes of Early Interention: A Key Issue in Rehabilitation and Screening

---

The Directorate for Research, Lifelong Learning and Employability would like to inform that approval is granted to **Pauline Miggiani** to conduct the research in State Schools according to the official rules and regulations, subject to approval from the Ethics Committee of the respective Higher Educational Institution.

The researcher is committed to comply with the Data Protection Act and will ensure that these requirements are followed in the conduct of this research.

Thank you for your attention and cooperation.

Ruth Muscat

Research Support Teacher

f/Grazio Grixti
Assistant Director (Research and Innovation)
Directorate for Research, Lifelong Learning and Employability
Great Siege Road | Floriana | VLT 2000
t: +356 25982265 **e:** grazio.grixti@ilearn.edu.mt | www.education.gov.mt

MINISTRY FOR EDUCATION AND EMPLOYMENT

Appendix D: LittlEARS® Information Letter and Consent Form

FORMOLA TA’ KUNSENS GĦAT-TESTIJIET KLINICI

L-iskop u d-dettalji tal-proġett dwar l-assesjar tas-smigħ spejgathomli Pauline Miggiani.

Jiena naf li l-informazzjoni miġbura ser tinżamm b’mod kunfidenzjali, u li ser tintuża biss għal skopijiet ta’ riċerka. Naf ukoll li l-iskop ta’ dan l-istudju huwa li jiġu żviluppati għodod kliniċi għall-evalwazzjoni tas-smigħ fi tfal żgħar. Jien naf ukoll li ser isir rapport bil-miktub tar-riżultati, u li meta jsir dan, jiena, jew it-tfal tiegħi bl-ebda mod ser inkunu nistgħu niġu identifikati. Kull informazzjoni ħa tkun protetta b’password u ħa tkun accessibbli biss minni u mis-superviżur tiegħi. Meta jispiċċa l-istudju, l-informazzjoni personali miġbura ser tiġi meqruda. Jiena nifhem li Pauline Miggiani se tħallini neżerċita d-drittijiet tiegħi taħt l-Att dwar il-Protezzjoni tad-Data biex naċċessa, nirrettifika u fejn applikabbli nħassar informazzjoni dwari jew dwar it-tfal tiegħi.

Jiena konxju li m'hemm l-ebda riskji prevedibbli (jew mistennija) meta nipparteċipa f'dan l-istudju.

Nikkonferma wkoll li t-tifel/ tifla tiegħi:

- Ma kienx tarbija prematura
- Ma kienx identifikat/a b’ nuqqas ta 'smigħ
- Ma għandux disturb newroloġiku

Għalhekk jiena, ________________________ qed nagħti l-kunsens tiegħi lill-persuna responsabbli għal din ir-riċerka, Pauline Miggiani, biex tagħmel l-osservazzjonijiet u t-testijiet li hemm bżonn sabiex tiġbor id-data meħtieġa. Naf li ma għandi l-ebda obbligu nagħmel dan, u li nista’ nirtira fi kwalunkwe punt, mingħajr ma nagħti raġuni.

Jekk jogħġbok ikkuntattjani fuq:

Ismi: __________________________________

Isem it-tifel/tifla: __________________________ Eta (tfal): _______________________

Telefown/Mowbajl: _______________________ Emejl: __________________________

Jekk ikolli diffikulta’ waqt l-istudju, nista’ nistaqsi għal Pauline Miggiani fuq in-numru tat-telefown: 79604896 jew emejl: pauline.miggiani@gov.mt

Isem tal-persuna responsabbli għall-istudju: Pauline Miggiani

CONSENT FORM FOR CLINICAL TESTS

The aims and details of the project on hearing testing have been explained to me by Pauline Miggiani.

I know that the information collected will remain confidential, and that it will be used only for research purposes. I am aware that the aim of the study is to develop clinical tools for assessing hearing in young children. I also know that a written report of the study will be drawn up, and that I will not be identified in any way in this report. I know that all data will be password protected and will be accessible only to the undersigned and the research supervisor Prof. Frans Coninx. Once the study is completed, all the personal information collected will be destroyed. I understand that the researcher will allow me to exercise my rights under the Data Protection Act to access, rectify, and where applicable erase the data concerning me and/or my children.

I am aware that there are no reasonable foreseeable (or expected) risks when participating in this study.

I also confirm that my child:

- Was not a premature baby
- Does not have an identified hearing loss
- Does not have a neurological disorder

I __________________________ therefore give my consent to Pauline Miggiani, the person responsible for the research, to collect the required data. I am aware that I am under no obligation to do so, and that I can withdraw my consent at any moment without giving any reason.

Kindly contact me on:

Name: ____________________________________

Child's Name: __________________________ Age: ____________________________

Tel/Mobile No: __________________________ Email: __________________________

In case of any difficulty during the study, I can contact Pauline Miggiani on 79604896 or email address: pauline.miggiani@gov.mt her supervisor Prof. Frans Coninx on f.coninx@ifap.info.

Name of person responsible for the study: Pauline Miggiani

Manjoe,
Triq C.Penza
Xgħajra

Għażiż Sinjur/Sinjura,

Jiena Awdjoloġista impjegata l- ENT Outpatients fl-isptar Mater Dei u qiegħda nagħmel Phd f'*Rehabilitation Sciences* mal-Universita` ta' Cologne, il- Ġermanja. Bħala parti minn dan il-kors jien se nkun qed immexxi studju ta' riċerka fost individwi Maltin li għandhom inqas minn 3 snin sabiex nevalwa żewġ testijiet tas-smigħ, wieħed bil-ħsejjes u l-ieħor bil-kliem. It-test ser iseħħ l-iskola jew fl- ENT Outpatients fl-Isptar Mater Dei.

Jekk taċċetta li tieħu sehem, iseħħ dan li ġej:

- Ħa tiġi mitlub timli kwestjonarju fuq is-smigħ tat-tifel jew tifla tiegħek billi tirrispondi iva/le għal 35 mistoqsijiet. Dan it-test se jieħu madwar 5 minuti.
- Is-smigħ tat-tifel/tifla tiegħek ħa jiġi evalwat b'test awtomatiku, OtoAcoustic Emissions (OAEs). Dan it-test jinvolvi li tiġi mpoġġija probe b' mikrofonu u speaker ġo widnejh/a. Ħsejjes jiġu ġenerati minn din il-*probe* u r-rispons tagħhom mill-organu tas-smigħ jiġi rrikordjat bħala PASS jew REFER fuq skrijn ta' kompjuter. Dan it-test se jieħu madwar 5 sa 10 minuti.

Jekk tixtieq tipparteċipa f'dan l-istudju ġentilment imla d-dettalji tiegħek fil-formola tal-kunsens sabiex inkun nista nagħmel kuntatt miegħek għal appuntament. Dan l-istudju se jgħin fl-iżvilupp ta' kwestjonarju fuq is-smigħ bil-Malti li għandu jintuża fil-kliniki bħala screening għal tfal żgħar.

Id-data kollha miġbura u kull informazzjoni li tista' tiżvela l-identità tiegħek ser tinżamm kunfidenzjali. Din se tkun protetta b'password u mhux se tiġi żvelata fi kwalunkwe punt fl-istudju. Id-data ser tintuża biss għal skopijiet ta' riċerka, u se tiġi meqruda ma' tmiem l-istudju. Jekk teħtieġ aktar informazzjoni jekk jogħġbok, toqgħodx lura milli tikkuntattjani fuq in-numru tat-telefon: 79604896 jew fuq l-indirizz eletroniku: pauline.miggiani@gov.mt.

Nirringrazzjak bil-quddiem.

Dejjem tiegħek,

__________________ __________________

Pauline Miggiani
Phd Student
Senior Audiologist

Prof. Frans Coninx
Project Supervisor

Manjoe,
Triq C. Penza,
Xgħajra

Dear Sir/Madam,

I am an Audiologist currently employed at ENT Outpatients at Mater Dei Hospital reading for a Phd in Rehabilitation Sciences at the University of Cologne, Germany. As part of this course I will be carrying out a research study in Maltese individuals under 3 years of age to examine the relationship between a hearing questionnaire and an automated hearing screening test. The test will be carried out at the playschool or at ENT Outpatients at Mater Dei Hospital.

If you agree to participate in the study, the following will occur:

- You will be asked to complete a questionnaire about your child's hearing. It is composed of 35 Yes/No questions. Tick yes if you have observed the behaviour at least on one occasion. The questionnaire will take approximately 3-5 minutes to complete.
- Your child's hearing will be screened using an automated hearing test, OtoAcoustic Emissions (OAEs). The test is performed by placing a small probe that contains a microphone and speaker into the child's ear. Sounds are generated in the probe and responses that come back from the cochlea are recorded and represented pictorially on a computer screen as a PASS or REFER. The test will take approximately 5 minutes.

If you would like to participate in this study kindly fill in your contact details in the consent form so that I will be able to contact you for an appointment. This study will help in the development of a Maltese auditory questionnaire test to be used in clinics when screening young children for hearing impairment.

Please note that all the data gathered and any information that may reveal your identity will be kept confidential and will not be disclosed at any point in the study. The data will be used only for scientific purposes. If you require further information please do not hesitate to contact me on telephone number: 79604896 or email address: pauline.miggiani@gov.mt

Thank you in anticipation.

Regards,

____

Pauline Miggiani
Phd Student
Senior Audiologist

____

Prof. Frans Coninx
Project Supervisor

Appendix E: AAST Information Letter and Consent Form

FORMOLA TA' KUNSENS GĦAT-TESTIJIET KLINICI

L-iskop u d-dettalji tal-proġett dwar l-assesjar tas-smigħ spejgathomli Pauline Miggiani.

Jiena naf li l-informazzjoni miġbura ser tinżamm b'mod kunfidenzjali, u li ser tintuża biss għal skopijiet ta' riċerka. Naf ukoll li l-iskop ta' dan l-istudju huwa li neżaminaw żewġ testijiet tas-smigħ wieħed bil-ħsejjes u l-ieħor bil-kliem. Jien naf ukoll li ser isir rapport bil-miktub tar-riżultati, u li meta jsir dan, jiena, jew it-tfal tiegħi bl-ebda mod ser inkunu nistgħu niġu identifikati. Kull informazzjoni ħa tkun protetta b'password u ħa tkun accessibbli biss minni u mis-superviżur tiegħi. Meta jispiċċa l-istudju, l-informazzjoni personali miġbura ser tiġi meqruda. Jiena nifhem li Pauline Miggiani se tħallini neżerċita d-drittijiet tiegħi taħt l-Att dwar il-Protezzjoni tad-Data biex naċċessa, nirrettifika u fejn applikabbli nħassar informazzjoni dwari jew dwar it-tfal tiegħi.

Jiena konxju li m'hemm l-ebda riskji prevedibbli (jew mistennija) meta nipparteċipa f'dan l-istudju.

Għalhekk jiena, ________________________ qed nagħti l-kunsens tiegħi lill-persuna responsabbli għal din ir-riċerka, Pauline Miggiani, biex tagħmel l-osservazzjonijiet u t-testijiet li hemm bżonn sabiex tiġbor id-data meħtieġa. Naf li ma għandi l-ebda obbligu nagħmel dan, u li nista' nirtira fi kwalunkwe punt, mingħajr ma nagħti raġuni.

Jekk jogħġbok ikkuntattjani fuq:

Ismi: __________________________________

Isem it-tifel/tifla: __________________________ Eta (tfal): _______________________

Telefown/Mowbajl: _______________________ Emejl: __________________________

Jekk ikolli diffikulta' waqt l-istudju, nista' nistaqsi għal Pauline Miggiani fuq in-numru tat-telefown: 79604896 jew emejl: pauline.miggiani@gov.mt jew is-superviżur Prof. Frans Coninx fuq f.coninx@ifap.info

Isem tal-persuna responsabbli għall-istudju: Pauline Miggiani

CONSENT FORM FOR CLINICAL TESTS

The aims and details of the project on hearing testing have been explained to me by Pauline Miggiani.

I know that the information collected will remain confidential, and that it will be used only for research purposes. I am aware that the aim of the study is to examine the relationship between two hearing tests, one with tones and one with words. I also know that a written report of the study will be drawn up, and that I or my children will not be identified in any way in this report. I know that all data will be password protected and will be accessible only to the undersigned and the research supervisor Prof. Frans Coninx. Once the study is completed, all the personal information collected will be destroyed. I understand that the researcher will allow me to exercise my rights under the Data Protection Act to access, rectify, and where applicable erase the data concerning me and/or my children.

I am aware that there are no reasonable foreseeable (or expected) risks when participating in this study.

I ________________________ therefore give my consent to Pauline Miggiani, the person responsible for the research, to collect the required data. I am aware that I am under no obligation to do so, and that I can withdraw my consent at any moment without giving any reason.

Kindly contact me on:

Name: _________________________________

Child's Name: ________________________ Age: __________________________

Tel/Mobile No: ________________________ Email: ________________________

In case of any difficulty during the study, I can contact Pauline Miggiani on 79604896 or email address: pauline.miggiani@gov.mt or her supervisor Prof. Frans Coninx on f.coninx@ifap.info.

Name of person responsible for the study: Pauline Miggiani

Għażiż Sinjur/Sinjura,

Jiena Awdjoloġista impjegata l- ENT Outpatients fl-isptar Mater Dei u qiegħda nagħmel Phd f'*Rehabilitation Sciences* mal-Universita` ta' Cologne, il- Ġermanja. Bħala parti minn dan il-kors jien se nkun qed immexxi studju ta' riċerka fost individwi Maltin li għandhom 'il fuq minn 3 snin sabiex nevalwa żewġ testijiet tas-smigħ, wieħed bil-ħsejjes u l-ieħor bil-kliem. It-test ser iseħħ l-iskola jew fl- ENT Outpatients fl-Isptar Mater Dei.

Jekk taċċetta li tieħu sehem, iseħħ dan li ġej:

- Ħa jsirlek screening tas-smigħ fejn inti/it-tifel/tifla tiegħek tisma 'ħoss u tindika jekk smajthomx jew le. Dan it-test se jieħu madwar 5 sa 10 minuti.
- Int ser tingħata 6 stampi fuq skrin tal-kompjuter u int se tintalab tuża l-headphones. Imbagħad int se tintalab tagħżel stampa minnhom b'livelli differenti . Dan it-test se jieħu madwar 5 minuti.

Jekk tixtieq tipparteċipa f'dan l-istudju ġentilment imla d-dettalji tiegħek fil-formola tal-kunsens sabiex inkun nista nagħmel kuntatt miegħek għal appuntament. Dan l-istudju se jgħin fl-iżvilupp ta' test tas-smigħ bil-Mlati li għandu jintuża fil-kliniki meta jiġu eżaminati tfal u adulti.

Id-data kollha miġbura u kull informazzjoni li tista' tiżvela l-identità tiegħek ser tinżamm kunfidenzjali. Din se tkun protetta b'password u mhux se tiġi żvelata fi kwalunkwe punt fl-istudju. Id-data ser tintuża biss għal skopijiet ta' riċerka, u se tiġi meqruda ma' tmiem l-istudju. Jekk teħtieġ aktar informazzjoni jekk jogħġbok, toqgħodx lura milli tikkuntattjani fuq in-numru tat-telefon: 79604896 jew fuq l-indirizz eletroniku: pauline.miggiani@gov.mt. Tista' ukoll tikkuntattja lis-superviżur tiegħi Prof. Frans Coninx fuq f.coninx@ifap.info

Nirringrazzjak bil-quddiem,

Dejjem tiegħek,

_________________ _________________

Pauline Miggiani
Phd Student
Senior Audiologist

Prof. Frans Coninx
Project Supervisor

Dear Sir/Madam,

I am an Audiologist currently employed at ENT Outpatients at Mater Dei Hospital reading for a Phd in Rehabilitation Sciences at the University of Cologne, Germany. As part of this course I will be carrying out a research study in Maltese individuals over 3 years of age to examine the relationship between two hearing tests, one with beeps and another one with words. The test will be carried out at ENT Outpatients at Mater Dei Hospital.

If you agree to participate in the study, the following will occur:

- You will receive a hearing screening where you will hear beeps and you will be asked to indicate whether or not you heard them. This test will take approximately 5 to 10 minutes.
- You will be shown 6 pictures on a computer screen and you will be asked to wear headphones. Then you will be asked to identify a picture at various loudness intensities. This test will take approximately 5 minutes.

If you would like to participate in this study kindly fill in your contact details in the consent form so that I will be able to contact you for an appointment. This study will help in the development of a Maltese speech test to be used in clinics when examining children and adults.

Please note that all the data gathered and any information that may reveal your identity will be kept confidential and will not be disclosed at any point in the study. The data will be used only for scientific purposes. If you require further information please do not hesitate to contact me on telephone number: 79604896 or email address: pauline.miggiani@gov.mt

Thank you in anticipation.

Regards,

________________ ________________

Pauline Miggiani
Phd Student
Senior Audiologist

Prof. Frans Coninx
Project Supervisor

Appendix F: Confusion Matrix Analysis

Confusion Matrix

Confusion matrix by Age

Adults		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	873	24	15	15	19	13
	key	13	867	42	38	20	15
	car	25	27	836	16	22	11
	glasses	13	74	11	833	67	2
	presents	4	6	12	88	932	2
	monkey	20	72	24	33	11	804
Total		948	1070	940	1023	1071	847

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	92.1%	2.2%	1.6%	1.5%	1.8%	1.5%
	key	1.4%	81.0%	4.5%	3.7%	1.9%	1.8%
	car	2.6%	2.5%	88.9%	1.6%	2.1%	1.3%
	glasses	1.4%	6.9%	1.2%	81.4%	6.3%	0.2%
	presents	0.4%	0.6%	1.3%	8.6%	87.0%	0.2%
	monkey	2.1%	6.7%	2.6%	3.2%	1.0%	94.9%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

10 year olds		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	809	17	20	13	17	17
	key	11	923	26	31	10	17
	car	23	17	839	7	13	6
	glasses	6	83	9	789	44	7
	presents	10	7	21	91	923	7
	monkey	12	73	15	29	10	781
Total		871	1120	930	960	1017	835

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	92.9%	1.5%	2.2%	1.4%	1.7%	2.0%
	key	1.3%	82.4%	2.8%	3.2%	1.0%	2.0%
	car	2.6%	1.5%	90.2%	0.7%	1.3%	0.7%
	glasses	0.7%	7.4%	1.0%	82.2%	4.3%	0.8%
	presents	1.1%	0.6%	2.3%	9.5%	90.8%	0.8%
	monkey	1.4%	6.5%	1.6%	3.0%	1.0%	93.5%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

7 year olds		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	1040	44	30	25	25	28
	key	31	1101	38	52	25	30
	car	42	28	1034	27	35	18
	glasses	18	99	29	1035	69	23
	presents	22	12	16	116	1080	18
	monkey	35	70	22	51	16	980
Total		1188	1354	1169	1306	1250	1097

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	87.5%	3.2%	2.6%	1.9%	2.0%	2.6%
	key	2.6%	81.3%	3.3%	4.0%	2.0%	2.7%
	car	3.5%	2.1%	88.5%	2.1%	2.8%	1.6%
	glasses	1.5%	7.3%	2.5%	79.2%	5.5%	2.1%
	presents	1.9%	0.9%	1.4%	8.9%	86.4%	1.6%
	monkey	2.9%	5.2%	1.9%	3.9%	1.3%	89.3%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6 year olds		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	775	22	26	32	28	16
	key	22	840	30	42	30	27
	car	44	26	736	25	25	15
	glasses	33	89	18	709	54	27
	presents	24	15	20	67	880	11
	monkey	29	44	18	48	36	794
Total		927	1036	848	923	1053	890

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	83.6%	2.1%	3.1%	3.5%	2.7%	1.8%
	key	2.4%	81.1%	3.5%	4.6%	2.8%	3.0%
	car	4.7%	2.5%	86.8%	2.7%	2.4%	1.7%
	glasses	3.6%	8.6%	2.1%	76.8%	5.1%	3.0%
	presents	2.6%	1.4%	2.4%	7.3%	83.6%	1.2%
	monkey	3.1%	4.2%	2.1%	5.2%	3.4%	89.2%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	836	30	29	28	29	31
	key	29	878	39	39	24	26
	car	32	25	843	30	29	16
	glasses	25	90	37	765	53	15
	presents	26	22	29	51	913	27
	monkey	47	63	22	29	46	731
Total		995	1108	999	942	1094	846

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	84.0%	2.7%	2.9%	3.0%	2.7%	3.7%
	key	2.9%	79.2%	3.9%	4.1%	2.2%	3.1%
	car	3.2%	2.3%	84.4%	3.2%	2.7%	1.9%
	glasses	2.5%	8.1%	3.7%	81.2%	4.8%	1.8%
	presents	2.6%	2.0%	2.9%	5.4%	83.5%	3.2%
	monkey	4.7%	5.7%	2.2%	3.1%	4.2%	86.4%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

4 year olds		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	892	22	24	26	53	31
	key	35	828	41	69	38	25
	car	42	30	872	36	41	35
	glasses	50	63	32	759	78	29
	presents	38	31	31	59	812	60
	monkey	63	51	21	40	67	794
Total		1120	1025	1021	989	1089	974

		ANSWER					
		snail	key	car	glasses	presents	monkey
STIMULUS_WORD	snail	79.6%	2.1%	2.4%	2.6%	4.9%	3.2%
	key	3.1%	80.8%	4.0%	7.0%	3.5%	2.6%
	car	3.8%	2.9%	85.4%	3.6%	3.8%	3.6%
	glasses	4.5%	6.1%	3.1%	76.7%	7.2%	3.0%
	presents	3.4%	3.0%	3.0%	6.0%	74.6%	6.2%
	monkey	5.6%	5.0%	2.1%	4.0%	6.2%	81.5%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Confusion matrix by Test Type

Confusion matrix in Quiet:

Adults

QUIET_NOISE_HIGH		ANSWER					
		snail	key	car	glasses	presents	monkey
QUIET	snail	296	8	3	1	6	5
	key	5	298	26	5	5	9
	car	5	15	276	7	6	4
	glasses	5	1	6	282	34	0
	presents	0	2	2	47	317	0
	monkey	3	26	13	4	5	303
Total		314	350	326	346	373	321

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	94.3%	2.3%	0.9%	0.3%	1.6%	1.6%
		key	1.6%	85.1%	8.0%	1.4%	1.3%	2.8%
		car	1.6%	4.3%	84.7%	2.0%	1.6%	1.2%
		glasses	1.6%	0.3%	1.8%	81.5%	9.1%	
		presents		0.6%	0.6%	13.6%	85.0%	
		monkey	1.0%	7.4%	4.0%	1.2%	1.3%	94.4%
Total			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

10 year olds

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	267	8	6	5	6	4
		key	3	321	19	4	4	10
		car	4	8	301	3	1	2
		glasses	2	5	2	273	24	2
		presents	0	1	1	57	352	2
		monkey	2	23	7	6	2	293
	Total		278	366	336	348	389	313

QUIET_NOISE_HIGH			ANSWER						
			snail	key	car	glasses	presents	monkey	?
QUIET	STIMULUS_WORD	snail	96.0%	2.2%	1.8%	1.4%	1.5%	1.3%	21.1%
		key	1.1%	87.7%	5.7%	1.1%	1.0%	3.2%	19.1%
		car	1.4%	2.2%	89.6%	0.9%	0.3%	0.6%	20.1%
		glasses	0.7%	1.4%	0.6%	78.4%	6.2%	0.6%	13.1%
		presents		0.3%	0.3%	16.4%	90.5%	0.6%	7.2%
		monkey	0.7%	6.3%	2.1%	1.7%	0.5%	93.6%	19.3%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

7 year olds

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	357	15	7	9	7	5
		key	9	379	24	5	7	12
		car	14	9	345	8	7	9
		glasses	6	9	5	375	44	10
		presents	5	2	3	59	389	3
		monkey	5	20	14	6	3	385
	Total		396	434	398	462	457	424

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	90.2%	3.5%	1.8%	1.9%	1.5%	1.2%
		key	2.3%	87.3%	6.0%	1.1%	1.5%	2.8%
		car	3.5%	2.1%	86.7%	1.7%	1.5%	2.1%
		glasses	1.5%	2.1%	1.3%	81.2%	9.6%	2.4%
		presents	1.3%	0.5%	0.8%	12.8%	85.1%	0.7%
		monkey	1.3%	4.6%	3.5%	1.3%	0.7%	90.8%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6 year olds

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	273	5	6	10	9	6
		key	7	262	17	11	10	10
		car	15	12	260	6	10	6
		glasses	11	10	10	261	26	7
		presents	6	5	6	30	349	2
		monkey	10	8	1	5	11	299
	Total		322	302	300	323	415	330

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	84.8%	1.7%	2.0%	3.1%	2.2%	1.8%
		key	2.2%	86.8%	5.7%	3.4%	2.4%	3.0%
		car	4.7%	4.0%	86.7%	1.9%	2.4%	1.8%
		glasses	3.4%	3.3%	3.3%	80.8%	6.3%	2.1%
		presents	1.9%	1.7%	2.0%	9.3%	84.1%	0.6%
		monkey	3.1%	2.6%	0.3%	1.5%	2.7%	90.6%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	313	13	10	5	10	10
		key	9	284	23	7	6	7
		car	9	5	285	12	11	6
		glasses	10	12	18	283	27	5
		presents	5	2	6	29	344	17
		monkey	14	17	9	4	18	320
	Total		360	333	351	340	416	365

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	86.9%	3.9%	2.8%	1.5%	2.4%	2.7%
		key	2.5%	85.3%	6.6%	2.1%	1.4%	1.9%
		car	2.5%	1.5%	81.2%	3.5%	2.6%	1.6%
		glasses	2.8%	3.6%	5.1%	83.2%	6.5%	1.4%
		presents	1.4%	0.6%	1.7%	8.5%	82.7%	4.7%
		monkey	3.9%	5.1%	2.6%	1.2%	4.3%	87.7%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

4 year olds

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	332	3	10	6	13	9
		key	9	292	20	20	12	9
		car	11	14	288	12	18	10
		glasses	17	9	16	288	32	8
		presents	16	11	9	30	293	20
		monkey	11	17	6	12	20	315
	Total		396	346	349	368	388	371

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
QUIET	STIMULUS_WORD	snail	83.8%	0.9%	2.9%	1.6%	3.4%	2.4%
		key	2.3%	84.4%	5.7%	5.4%	3.1%	2.4%
		car	2.8%	4.0%	82.5%	3.3%	4.6%	2.7%
		glasses	4.3%	2.6%	4.6%	78.3%	8.2%	2.2%
		presents	4.0%	3.2%	2.6%	8.2%	75.5%	5.4%
		monkey	2.8%	4.9%	1.7%	3.3%	5.2%	84.9%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Confusion matrix in Noise:

Adults

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE		snail	268	13	8	7	7	3
		key	5	260	12	6	14	1
		car	10	5	269	6	7	4
		glasses	5	5	3	283	31	1
		presents	0	1	1	28	308	1
		monkey	11	16	6	13	6	230
	Total		299	300	299	343	373	240

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	89.6%	4.3%	2.7%	2.0%	1.9%	1.3%
		key	1.7%	86.7%	4.0%	1.7%	3.8%	0.4%
		car	3.3%	1.7%	90.0%	1.7%	1.9%	1.7%
		glasses	1.7%	1.7%	1.0%	82.5%	8.3%	0.4%
		presents		0.3%	0.3%	8.2%	82.6%	0.4%
		monkey	3.7%	5.3%	2.0%	3.8%	1.6%	95.8%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

10 year olds

QUIET_NOISE_HIGH			ANSWER						
			snail	key	car	glasses	presents	monkey	?
NOISE	STIMULUS_WORD	snail	230	4	13	5	5	6	99
		key	7	250	6	2	3	4	73
		car	3	1	260	1	3	2	84
		glasses	1	14	4	266	19	3	67
		presents	4	3	5	29	258	2	47
		monkey	7	15	5	5	5	227	62
	Total		252	287	293	308	293	244	432

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	91.3%	1.4%	4.4%	1.6%	1.7%	2.5%
		key	2.8%	87.1%	2.0%	0.6%	1.0%	1.6%
		car	1.2%	0.3%	88.7%	0.3%	1.0%	0.8%
		glasses	0.4%	4.9%	1.4%	86.4%	6.5%	1.2%
		presents	1.6%	1.0%	1.7%	9.4%	88.1%	0.8%
		monkey	2.8%	5.2%	1.7%	1.6%	1.7%	93.0%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

7 year olds

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	285	18	16	14	6	14
		key	17	308	8	9	15	10
		car	12	10	343	9	11	4
		glasses	8	14	14	306	17	7
		presents	3	2	6	42	304	8
		monkey	12	20	5	19	8	272
	Total		337	372	392	399	361	315

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	84.6%	4.8%	4.1%	3.5%	1.7%	4.4%
		key	5.0%	82.8%	2.0%	2.3%	4.2%	3.2%
		car	3.6%	2.7%	87.5%	2.3%	3.0%	1.3%
		glasses	2.4%	3.8%	3.6%	76.7%	4.7%	2.2%
		presents	0.9%	0.5%	1.5%	10.5%	84.2%	2.5%
		monkey	3.6%	5.4%	1.3%	4.8%	2.2%	86.3%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6 year olds

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	212	12	14	15	15	5
		key	11	251	5	3	14	6
		car	8	7	219	13	7	1
		glasses	13	12	4	206	21	13
		presents	3	5	5	28	263	6
		monkey	11	15	6	17	17	241
	Total		258	302	253	282	337	272

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	82.2%	4.0%	5.5%	5.3%	4.5%	1.8%
		key	4.3%	83.1%	2.0%	1.1%	4.2%	2.2%
		car	3.1%	2.3%	86.6%	4.6%	2.1%	0.4%
		glasses	5.0%	4.0%	1.6%	73.0%	6.2%	4.8%
		presents	1.2%	1.7%	2.0%	9.9%	78.0%	2.2%
		monkey	4.3%	5.0%	2.4%	6.0%	5.0%	88.6%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	216	6	13	15	10	13
		key	15	285	8	10	14	11
		car	10	7	268	9	9	6
		glasses	6	14	10	214	20	6
		presents	9	11	9	12	288	5
		monkey	14	16	6	7	17	199
	Total		270	339	314	267	358	240

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	80.0%	1.8%	4.1%	5.6%	2.8%	5.4%
		key	5.6%	84.1%	2.5%	3.7%	3.9%	4.6%
		car	3.7%	2.1%	85.4%	3.4%	2.5%	2.5%
		glasses	2.2%	4.1%	3.2%	80.1%	5.6%	2.5%
		presents	3.3%	3.2%	2.9%	4.5%	80.4%	2.1%
		monkey	5.2%	4.7%	1.9%	2.6%	4.7%	82.9%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	245	11	8	10	25	11
		key	11	239	11	15	15	9
		car	14	8	265	12	12	13
		glasses	14	13	9	242	27	14
		presents	9	5	11	21	266	19
		monkey	27	11	8	16	22	252
	Total		320	287	312	316	367	318

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
NOISE	STIMULUS_WORD	snail	76.6%	3.8%	2.6%	3.2%	6.8%	3.5%
		key	3.4%	83.3%	3.5%	4.7%	4.1%	2.8%
		car	4.4%	2.8%	84.9%	3.8%	3.3%	4.1%
		glasses	4.4%	4.5%	2.9%	76.6%	7.4%	4.4%
		presents	2.8%	1.7%	3.5%	6.6%	72.5%	6.0%
		monkey	8.4%	3.8%	2.6%	5.1%	6.0%	79.2%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Confusion matrix in High Frequency:

Adults

QUIET_NOISE_HIGH		ANSWER					
		snail	key	car	glasses	presents	monkey
HIGH	snail	309	3	4	7	6	5
	key	3	309	4	27	1	5
	car	10	7	291	3	9	3
	glasses	3	68	2	268	2	1
	presents	4	3	9	13	307	1
	monkey	6	30	5	16	0	271
Total		335	420	315	334	325	286

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	92.2%	0.7%	1.3%	2.1%	1.8%	1.7%
		key	0.9%	73.6%	1.3%	8.1%	0.3%	1.7%
		car	3.0%	1.7%	92.4%	0.9%	2.8%	1.0%
		glasses	0.9%	16.2%	0.6%	80.2%	0.6%	0.3%
		presents	1.2%	0.7%	2.9%	3.9%	94.5%	0.3%
		monkey	1.8%	7.1%	1.6%	4.8%		94.8%
Total			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

10 year olds

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	312	5	1	3	6	7
		key	1	352	1	25	3	3
		car	16	8	278	3	9	2
		glasses	3	64	3	250	1	2
		presents	6	3	15	5	313	3
		monkey	3	35	3	18	3	261
Total			341	467	301	304	335	278

QUIET_NOISE_HIGH			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	91.5%	1.1%	0.3%	1.0%	1.8%	2.5%
		key	0.3%	75.4%	0.3%	8.2%	0.9%	1.1%
		car	4.7%	1.7%	92.4%	1.0%	2.7%	0.7%
		glasses	0.9%	13.7%	1.0%	82.2%	0.3%	0.7%
		presents	1.8%	0.6%	5.0%	1.6%	93.4%	1.1%
		monkey	0.9%	7.5%	1.0%	5.9%	0.9%	93.9%
Total			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

7 year olds

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	398	11	7	2	12	9
		key	5	414	6	38	3	8
		car	16	9	346	10	17	5
		glasses	4	76	10	354	8	6
		presents	14	8	7	15	387	7
		monkey	18	30	3	26	5	323
	Total		455	548	379	445	432	358

Quiet_Noise_High_7yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	87.5%	2.0%	1.8%	0.4%	2.8%	2.5%
		key	1.1%	75.5%	1.6%	8.5%	0.7%	2.2%
		car	3.5%	1.6%	91.3%	2.2%	3.9%	1.4%
		glasses	0.9%	13.9%	2.6%	79.6%	1.9%	1.7%
		presents	3.1%	1.5%	1.8%	3.4%	89.6%	2.0%
		monkey	4.0%	5.5%	0.8%	5.8%	1.2%	90.2%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6 year olds

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	290	5	6	7	4	5
		key	4	327	8	28	6	11
		car	21	7	257	6	8	8
		glasses	9	67	4	242	7	7
		presents	15	5	9	9	268	3
		monkey	8	21	11	26	8	254
	Total		347	432	295	318	301	288

Quiet_Noise_High_6yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	83.6%	1.2%	2.0%	2.2%	1.3%	1.7%
		key	1.2%	75.7%	2.7%	8.8%	2.0%	3.8%
		car	6.1%	1.6%	87.1%	1.9%	2.7%	2.8%
		glasses	2.6%	15.5%	1.4%	76.1%	2.3%	2.4%
		presents	4.3%	1.2%	3.1%	2.8%	89.0%	1.0%
		monkey	2.3%	4.9%	3.7%	8.2%	2.7%	88.2%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	307	11	6	8	9	8
		key	5	309	8	22	4	8
		car	13	13	290	9	9	4
		glasses	9	64	9	268	6	4
		presents	12	9	14	10	281	5
		monkey	19	30	7	18	11	212
	Total		365	436	334	335	320	241

Quiet_Noise_High_5yrs			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	84.1%	2.5%	1.8%	2.4%	2.8%	3.3%
		key	1.4%	70.9%	2.4%	6.6%	1.3%	3.3%
		car	3.6%	3.0%	86.8%	2.7%	2.8%	1.7%
		glasses	2.5%	14.7%	2.7%	80.0%	1.9%	1.7%
		presents	3.3%	2.1%	4.2%	3.0%	87.8%	2.1%
		monkey	5.2%	6.9%	2.1%	5.4%	3.4%	88.0%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5 year olds

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	315	8	6	10	15	11
		key	15	297	10	34	11	7
		car	17	8	319	12	11	12
		glasses	19	41	7	229	19	7
		presents	13	15	11	8	253	21
		monkey	25	23	7	12	25	227
	Total		404	392	360	305	334	285

Quiet_Noise_High			ANSWER					
			snail	key	car	glasses	presents	monkey
HIGH	STIMULUS_WORD	snail	78.0%	2.0%	1.7%	3.3%	4.5%	3.9%
		key	3.7%	75.8%	2.8%	11.1%	3.3%	2.5%
		car	4.2%	2.0%	88.6%	3.9%	3.3%	4.2%
		glasses	4.7%	10.5%	1.9%	75.1%	5.7%	2.5%
		presents	3.2%	3.8%	3.1%	2.6%	75.7%	7.4%
		monkey	6.2%	5.9%	1.9%	3.9%	7.5%	79.6%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix G: Response Time Analysis according to Stimulus Words

Appendix G: Response Time Analysis

Is there a significant difference in response time across stimulus words?

The mean ranks of stimulus words is tabulated below (age not accounted for). There is a significant difference (p<0.05). as seen in the test below. As seen in the pairwise comparisons table, there is a significant difference across almost all stimulus words, except car-key and presents-monkey. Response time is thus longest in 'glasses' followed by snail, monkey and presents, key and car.

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	7323	25489
	snail	7358	22501
	monkey	7188	21844
	presents	7368	21518
	key	7361	20562
	car	7531	20524
	Total	44129	

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of RESP_TIME is the same across categories of STIMULUS_WORD.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
car-key	38.376	208.707	.184	.854
car-presents	-994.220	208.657	-4.765	.000
car-monkey	-1,319.500	209.974	-6.284	.000
car-snail	1,976.914	208.729	9.471	.000
car-glasses	-4,965.342	208.981	-23.760	.000
key-presents	-955.843	209.845	-4.555	.000
key-monkey	-1,281.124	211.154	-6.067	.000
key-snail	1,938.538	209.917	9.235	.000
key-glasses	-4,926.965	210.167	-23.443	.000
presents-monkey	-325.280	211.105	-1.541	.123
presents-snail	982.694	209.867	4.682	.000
presents-glasses	3,971.122	210.118	18.900	.000
monkey-snail	657.414	211.176	3.113	.002
monkey-glasses	3,645.842	211.425	17.244	.000
snail-glasses	-2,988.428	210.189	-14.218	.000

Summary of detailed results below.

When age is accounted for,

- Glasses still reports the longest response time across all ages
- Shortest 3, key car presents, longest 3 snail monkey glasses

Details by age: 4 yrs

In 4 year olds, glasses has significantly the longest response time.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
car-key	154.702	84.221	1.837	.066
car-snail	161.424	83.615	1.931	.054
car-monkey	-262.832	84.368	-3.115	.002
car-presents	-368.234	84.555	-4.355	.000
car-glasses	-728.484	84.295	-8.642	.000
key-snail	6.723	85.157	.079	.937
key-monkey	-108.130	85.896	-1.259	.208
key-presents	-213.532	86.079	-2.481	.013
key-glasses	-573.783	85.824	-6.686	.000
snail-monkey	-101.407	85.302	-1.189	.235
snail-presents	-206.809	85.486	-2.419	.016
snail-glasses	-567.060	85.229	-6.653	.000
monkey-presents	105.402	86.223	1.222	.222
monkey-glasses	465.653	85.968	5.417	.000
presents-glasses	360.251	86.151	4.182	.000

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1191	4086.70
	presents	1177	3726.45
	monkey	1187	3621.05
	snail	1229	3519.64
	key	1195	3512.92
	car	1286	3358.22

Details by age: 5 yrs

As shown in the tables below, glasses has statistically the longest response time.

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1175	4227.07
	monkey	1116	3562.78
	snail	1195	3516.83
	key	1185	3416.84
	presents	1211	3394.09
	car	1222	3217.90

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
car-presents	-176.187	83.126	-2.120	.034
car-key	198.939	83.583	2.380	.017
car-snail	298.925	83.405	3.584	.000
car-monkey	-344.877	84.885	-4.063	.000
car-glasses	-1,009.172	83.763	-12.048	.000
presents-key	22.752	83.770	.272	.786
presents-snail	122.739	83.592	1.468	.142
presents-monkey	-168.690	85.069	-1.983	.047
presents-glasses	832.986	83.950	9.922	.000
key-snail	99.987	84.047	1.190	.234
key-monkey	-145.938	85.515	-1.707	.088
key-glasses	-810.234	84.402	-9.600	.000
snail-monkey	-45.951	85.341	-.538	.590
snail-glasses	-710.247	84.226	-8.433	.000
monkey-glasses	664.296	85.691	7.752	.000

Details by age: 6 yrs

As shown in the tables below, glasses has statistically the longest response time

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1118	3804.31
	monkey	1118	3346.35
	snail	1079	3345.41
	key	1132	3213.39
	presents	1127	3185.04
	car	1103	3139.86
	Total	6677	

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
car-presents	-45.185	81.613	-.554	.580
car-key	73.529	81.523	.902	.367
car-snail	205.550	82.506	2.491	.013
car-monkey	-206.491	81.775	-2.525	.012
car-glasses	-664.450	81.775	-8.125	.000
presents-key	28.344	81.083	.350	.727
presents-snail	160.365	82.070	1.954	.051
presents-monkey	-161.306	81.335	-1.983	.047
presents-glasses	619.265	81.335	7.614	.000
key-snail	132.021	81.981	1.610	.107
key-monkey	-132.961	81.246	-1.637	.102
key-glasses	-590.920	81.246	-7.273	.000
snail-monkey	-.941	82.231	-.011	.991
snail-glasses	-458.899	82.231	-5.581	.000
monkey-glasses	457.959	81.498	5.619	.000

Details by age: 7 yrs
Similarly, glasses significantly longer response time.

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1516	5051.79
	snail	1458	4381.71
	monkey	1395	4336.81
	presents	1430	4322.39
	car	1516	4136.00
	key	1460	4079.87
	Total	8775	

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
key-car	-56.130	92.848	-.605	.545
key-presents	-242.526	94.208	-2.574	.010
key-monkey	-256.939	94.803	-2.710	.007
key-snail	301.840	93.750	3.220	.001
key-glasses	-971.919	92.848	-10.468	.000
car-presents	-186.395	93.343	-1.997	.046
car-monkey	-200.809	93.944	-2.138	.033
car-snail	245.710	92.881	2.645	.008
car-glasses	-915.789	91.971	-9.957	.000
presents-monkey	-14.413	95.288	-.151	.880
presents-snail	59.315	94.240	.629	.529
presents-glasses	729.394	93.343	7.814	.000
monkey-snail	44.901	94.835	.473	.636
monkey-glasses	714.980	93.944	7.611	.000
snail-glasses	-670.079	92.881	-7.214	.000

Details by age: 10 yrs

Similarly, glasses significantly longer response time, followed by snail.

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1124	4236.75
	snail	1146	3754.81
	monkey	1131	3376.59
	presents	1211	3304.75
	car	1173	3240.57
	key	1209	3121.77
	Total	6994	

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
key-car	-118.802	82.700	-1.437	.151
key-presents	-182.981	82.039	-2.230	.026
key-monkey	-254.814	83.476	-3.053	.002
key-snail	633.043	83.193	7.609	.000
key-glasses	-1,114.981	83.610	-13.335	.000
car-presents	-64.179	82.667	-.776	.438
car-monkey	-136.012	84.093	-1.617	.106
car-snail	514.241	83.812	6.136	.000
car-glasses	-996.179	84.226	-11.827	.000
presents-monkey	-71.833	83.443	-.861	.389
presents-snail	450.062	83.160	5.412	.000
presents-glasses	932.000	83.577	11.151	.000
monkey-snail	378.229	84.578	4.472	.000
monkey-glasses	860.167	84.988	10.121	.000
snail-glasses	-481.938	84.710	-5.689	.000

Details by age: Adults

Similarly, glasses, significantly longer response time, followed by snail, monkey and presents, car and shortest response time by key.

	STIMULUS_WORD	N	Mean Rank
RESP_TIME	glasses	1157	4222.79
	snail	1193	3867.73
	monkey	1184	3490.48
	presents	1155	3435.29
	car	1171	3127.67
	key	1146	2864.36
	Total	7006	

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
key-car	-263.312	83.972	-3.136	.002	.026
key-presents	-570.928	84.259	-6.776	.000	.000
key-monkey	-626.122	83.743	-7.477	.000	.000
key-snail	1,003.365	83.588	12.004	.000	.000
key-glasses	-1,358.424	84.223	-16.129	.000	.000
car-presents	-307.616	83.806	-3.671	.000	.004
car-monkey	-362.811	83.288	-4.356	.000	.000
car-snail	740.053	83.132	8.902	.000	.000
car-glasses	-1,095.113	83.770	-13.073	.000	.000
presents-monkey	-55.194	83.577	-.660	.509	1.000
presents-snail	432.437	83.422	5.184	.000	.000
presents-glasses	787.496	84.058	9.369	.000	.000
monkey-snail	377.243	82.901	4.551	.000	.000
monkey-glasses	732.302	83.541	8.766	.000	.000
snail-glasses	-355.059	83.385	-4.258	.000	.000

1. **Is there a significant difference in response time in words that are correct/wrong?**

As seen in the table below, there is a significant difference in response time between correct answers and wrong answers. The mean ranks table shows that correct answers have a significant shorter response time than wrong answers. This has been tested in all age groups, yielding similar results.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of RESP_TIME is the same across categories of Correct_Wrong.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

	Correct_Wrong	N	Mean Rank	Sum of Ranks
RESP_TIME	Correct	31353	21271	666898971
	Wrong	12776	24014	306807414

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of RESP_TIME is the same across categories of Correct_Wrong_4yrs.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
2	The distribution of RESP_TIME is the same across categories of Correct_Wrong_5yrs.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
3	The distribution of RESP_TIME is the same across categories of Correct_Wrong_6yrs.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
4	The distribution of RESP_TIME is the same across categories of Correct_Wrong_7yrs.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
5	The distribution of RESP_TIME is the same across categories of Correct_Wrong_10yrs.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
6	The distribution of RESP_TIME is the same across categories of Correct_Wrong_Adults	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

2. **Is there a correlation between response time and threshold?**

There is a very low correlation between threshold and response time. When age is accounted for, similar results emerge. There is a very low correlation between response time and thresholds across all ages.

		RESP_TIME	AVG
RESP_TIME	Pearson Correlation	1	.018**
	Sig. (2-tailed)		.000
	N	44129	44129
AVG	Pearson Correlation	.018**	1
	Sig. (2-tailed)	.000	
	N	44129	44129

**. Correlation is significant at the 0.01 level (2-tailed).

RESP_TIME AVG			
RESP_TIME_4yrs	Pearson Correlation	1.000	.021
	Sig. (2-tailed)		.075
	N	7265	7265
RESP_TIME_5yrs	Pearson Correlation	1.000	-0.000
	Sig. (2-tailed)		.980
	N	7104	7104
RESP_TIME_6yrs	Pearson Correlation	1.000	-.017
	Sig. (2-tailed)		.160
	N	6677	6677
RESP_TIME_7yrs	Pearson Correlation	1.000	-0.027**
	Sig. (2-tailed)		.012
	N	8775	7006
RESP_TIME_10yrs	Pearson Correlation	1.000	-0.051**
	Sig. (2-tailed)		.000
	N	6994	6994
RESP_TIME_Adults	Pearson Correlation	1.000	.010
	Sig. (2-tailed)		.400
	N	7006	7006

**. Correlation is significant at the 0.01 level (2-tailed)

3. **Is there a correlation between response time and intensity?**

There is a very low correlation between threshold and response time. When age is accounted for, similar results emerge. There is a very low correlation between response time and intensity across all ages.

		RESP_TIME	INTENSITY
RESP_TIME	Pearson Correlation	1	-.015**
	Sig. (2-tailed)		.002
	N	44129	44129
INTENSITY	Pearson Correlation	-.015**	1
	Sig. (2-tailed)	.002	
	N	44129	44129

**. Correlation is significant at the 0.01 level (2-tailed).

		RESP_TIME	INTENSITY
RESP_TIME_4yrs	Pearson Correlation	1.000	.010
	Sig. (2-tailed)		.390
	N	7265	7265
RESP_TIME_5yrs	Pearson Correlation	1.000	-0.061**
	Sig. (2-tailed)		.000
	N	7104	7104
RESP_TIME_6yrs	Pearson Correlation	1.000	-.114**
	Sig. (2-tailed)		.000
	N	6677	6677
RESP_TIME_7yrs	Pearson Correlation	1.000	-0.068**
	Sig. (2-tailed)		.000
	N	8775	7006
RESP_TIME_10yrs	Pearson Correlation	1.000	-0.091**
	Sig. (2-tailed)		.000
	N	6994	6994
RESP_TIME_Adults	Pearson Correlation	1.000	.034
	Sig. (2-tailed)		.004
	N	7006	7006

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix H: Reversal points Analysis

Reversals- Analysis by age

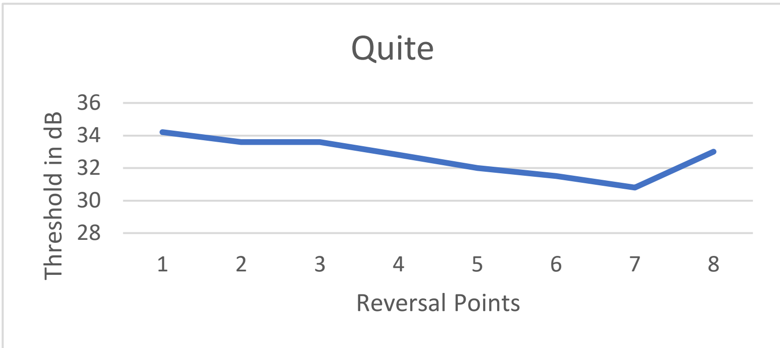
4 years

Reversal	Quite (NOT)	Noise	High Frequency
1	34.2	-14.4	40.9
2	33.6	-13.4	41.3
3	33.6	-12.8	41.3
4	32.8	-12.6	41.5
5	32	-12.5	40.4
6	31.5	-12.5	39.7
7	30.8	-12.7	38.4
8	33	-12.1	38.5

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1.000-2.000	-60.889	24.083	-2.528	.011	.241
1.000-3.000	-103.298	24.158	-4.276	.000	.000
1.000-7.000	-109.273	26.105	-4.186	.000	.001
1.000-4.000	-111.603	24.235	-4.605	.000	.000
1.000-5.000	-118.629	24.235	-4.895	.000	.000
1.000-6.000	-120.853	24.824	-4.868	.000	.000

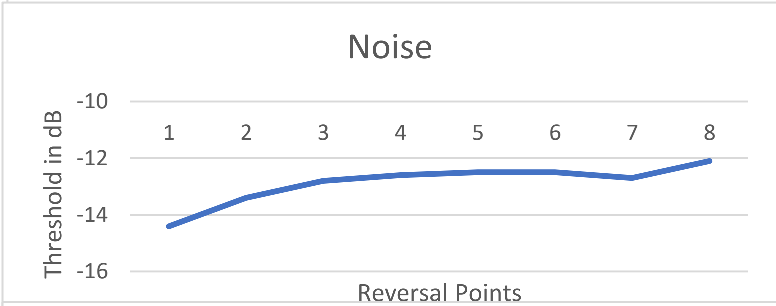
Test Statistics quiet

	SRT
Chi-Square	2.949
df	6
Asymp. Sig.	.815



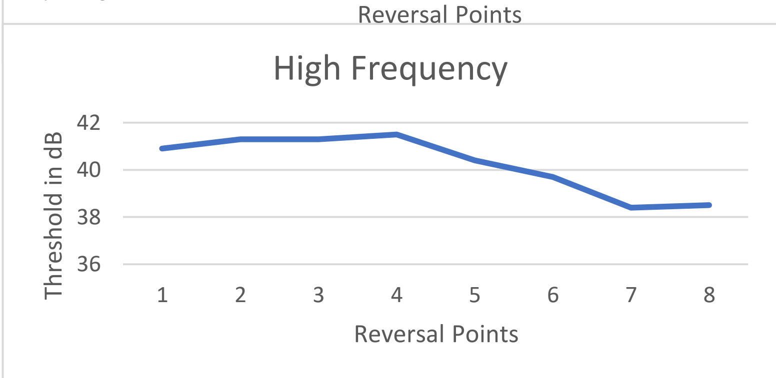
Test Statistics noise

	SRT
Chi-Square	39.527
df	6
Asymp. Sig.	.000



Test Statistics high

	SRT
Chi-Square	3.384
df	6
Asymp. Sig.	.759



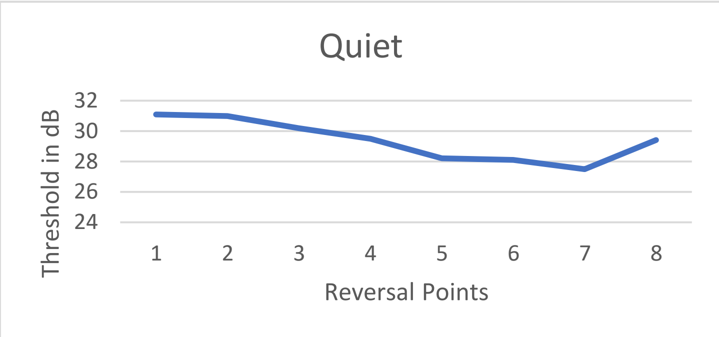
5 years

Reversal	Quite	Noise	High Frequency
1	31.1	-14.7	36.3
2	31	-13.9	35.8
3	30.2	-13.6	35.5
4	29.5	-13.7	36.1
5	28.2	-13.9	35.9
6	28.1	-13.9	35.4
7	27.5	-13.9	35.1
8	29.4	-14.1	36.4

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1.000-2.000	-102.838	24.496	-4.198	.000	.001
1.000-5.000	-105.095	24.988	-4.206	.000	.001
1.000-6.000	-108.155	24.988	-4.328	.000	.000
1.000-7.000	-109.500	24.988	-4.382	.000	.000
1.000-4.000	-114.718	24.734	-4.638	.000	.000
1.000-3.000	-126.581	24.496	-5.167	.000	.000

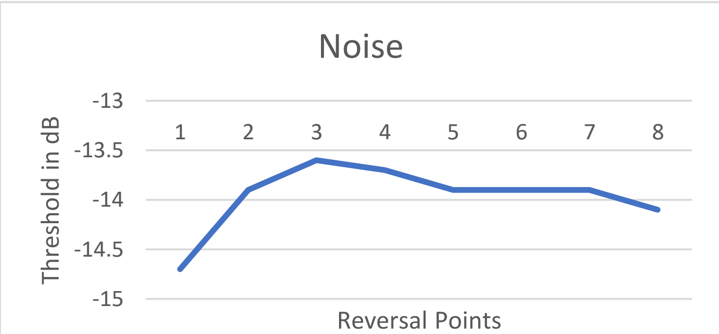
Quiet Test Statistics[a,b]

	SRT
Chi-Square	2.657
df	6
Asymp. Sig.	.851



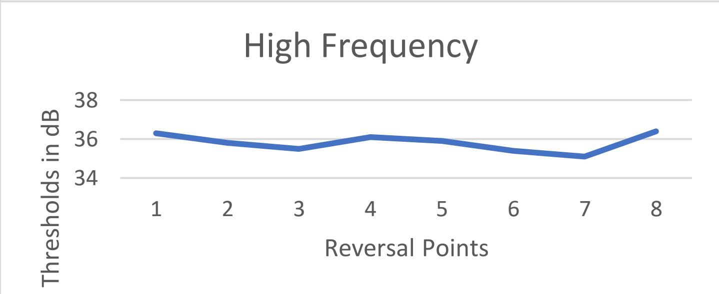
Noise Test Statistics[a,b]

	SRT
Chi-Square	36.351
df	6
Asymp. Sig.	.000



High Test Statistics[a,b]

	SRT
Chi-Square	.635
df	6
Asymp. Sig.	.996



6 years

Reversal	Quite	Noise	High Frequency
1	27.1	-15.9	31.9
2	26.1	-15.2	32.5
3	25.7	-14.9	32.9
4	25.5	-14.8	33.2
5	25.5	-14.7	33.1
6	25.3	-14.6	33.1
7	25.2	-14.6	32.7
8	27.6	-16.1	34

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1.000-2.000	-67.737	24.275	-2.790	.005	.111
1.000-3.000	-81.303	24.275	-3.349	.001	.017
1.000-4.000	-86.851	24.356	-3.566	.000	.008
1.000-5.000	-95.177	24.356	-3.908	.000	.002
1.000-7.000	-105.226	24.790	-4.245	.000	.000
1.000-6.000	-111.444	24.523	-4.544	.000	.000

Test Statistics[a,b]

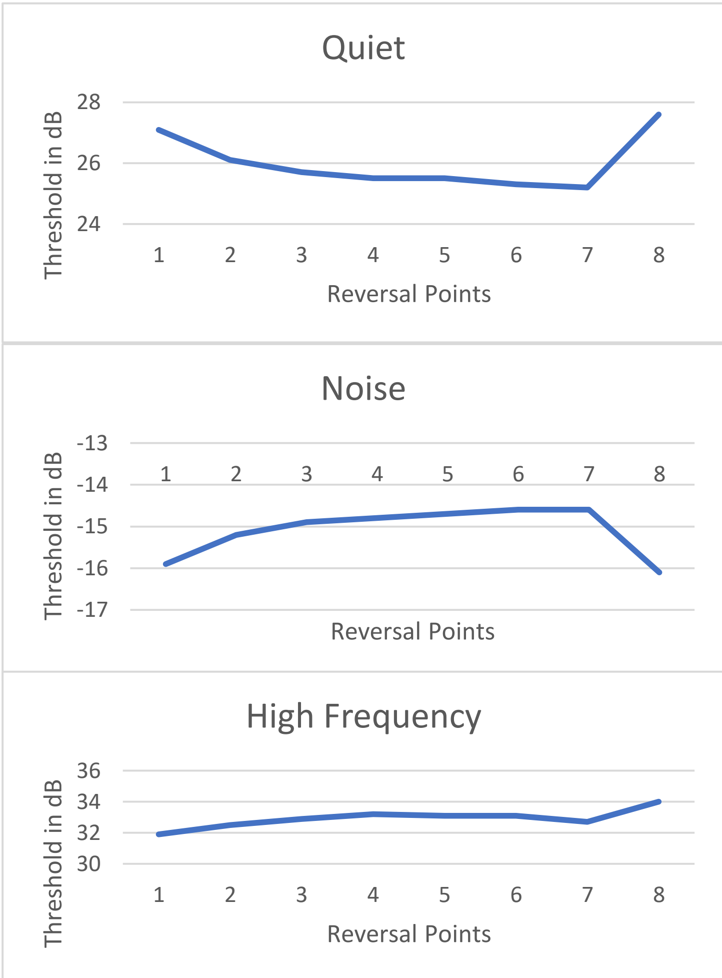
	SRT
Chi-Square	.120
df	6
Asymp. Sig.	1.000

Test Statistics[a,b]

	SRT
Chi-Square	28.256
df	6
Asymp. Sig.	.000

Test Statistics[a,b]

	SRT
Chi-Square	7.483
df	6
Asymp. Sig.	.279



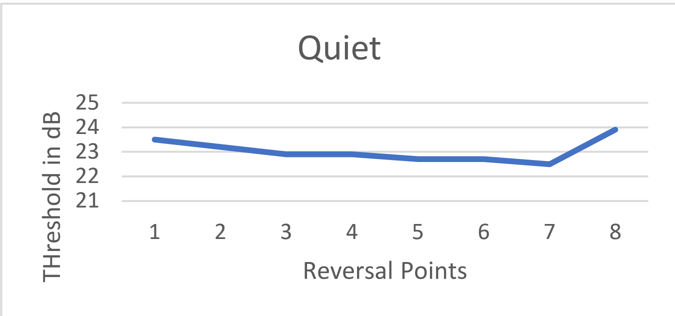
7 years

Reversal	Quite	Noise	High Frequency
1	23.5	-16.1	30.6
2	23.2	-15.4	30.9
3	22.9	-15.3	30.7
4	22.9	-15.2	30.6
5	22.7	-15.2	30.6
6	22.7	-15.1	30.5
7	22.5	-15.1	30.2
8	23.9	-14.7	29.7

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1.000-3.000	-68.730	28.078	-2.448	.014	.302
1.000-4.000	-78.724	28.148	-2.797	.005	.108
1.000-2.000	-80.926	28.078	-2.882	.004	.083
1.000-5.000	-83.743	28.218	-2.968	.003	.063
1.000-6.000	-88.783	28.218	-3.146	.002	.035
1.000-7.000	-93.712	28.514	-3.287	.001	.021

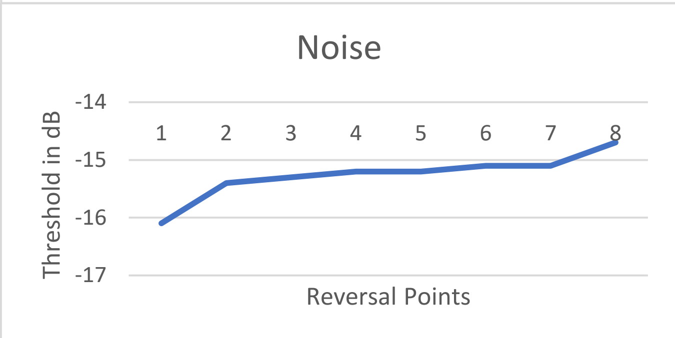
Quiet Test Statistics[a,b]

	SRT
Chi-Square	1.508
df	6
Asymp. Sig.	.959



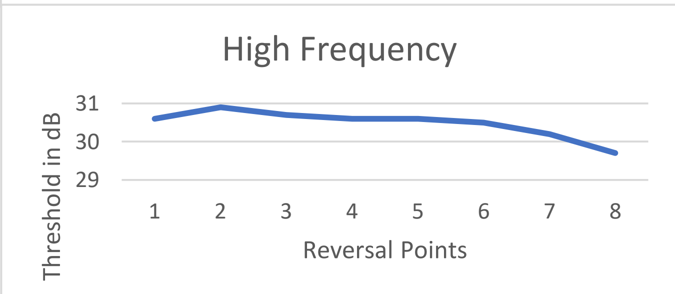
Noise Test Statisticsa,b

	SRT
Chi-Square	15.616
df	6
Asymp. Sig.	.016



High Test Statisticsa,b

	SRT
Chi-Square	3.470
df	6
Asymp. Sig.	.748

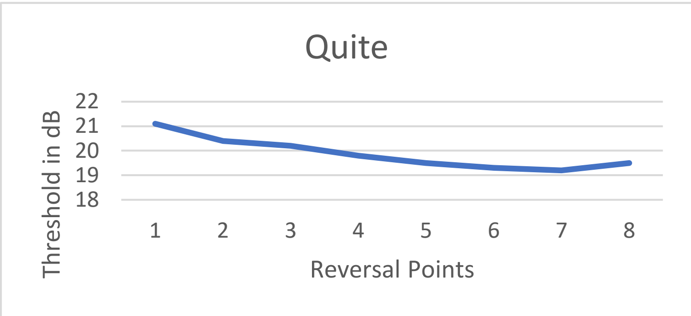


10 years

Reversal	Quite	Noise	High Frequency
1	21.1	-16.4	26
2	20.4	-15.8	26.1
3	20.2	-15.6	26
4	19.8	-15.6	25.9
5	19.5	-15.6	25.8
6	19.3	-15.6	25.8
7	19.2	-15.6	25.8
8	19.5	-16.2	27.9

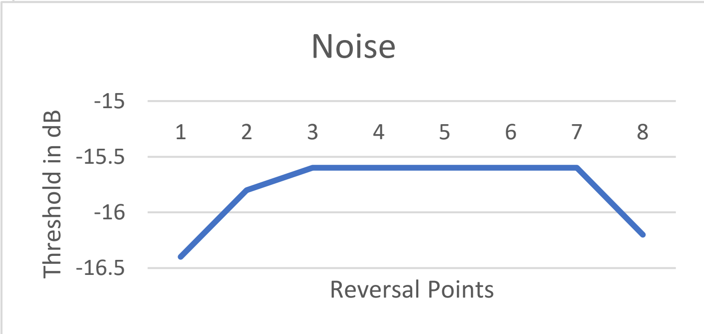
Test Statistics[a,b]

	SRT
Chi-Square	5.315
df	6
Asymp. Sig.	.504



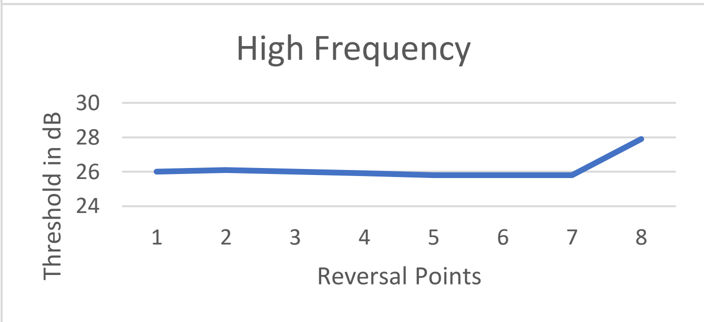
Test Statistics[a,b]

	SRT
Chi-Square	3.776
df	6
Asymp. Sig.	.707



Test Statistics[a,b]

	SRT
Chi-Square	.571
df	6
Asymp. Sig.	.997



Adults

Reversal	Quite	Noise	High Frequency
1	20.1	-16.7	29.4
2	20.1	-16.2	28.5
3	19.8	-16	28.5
4	19.6	-16	28.1
5	19.3	-16	27.9
6	19.3	-16	27.7
7	19.3	-16	27.8
8	21.6	-2.7	28.4

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1.000-2.000	-105.062	25.305	-4.152	.000	.001
1.000-3.000	-139.350	25.305	-5.507	.000	.000
1.000-5.000	-146.038	25.305	-5.771	.000	.000
1.000-6.000	-146.506	25.305	-5.790	.000	.000
1.000-7.000	-146.662	25.305	-5.796	.000	.000
1.000-4.000	-149.338	25.305	-5.901	.000	.000

Test Statistics[a,b]

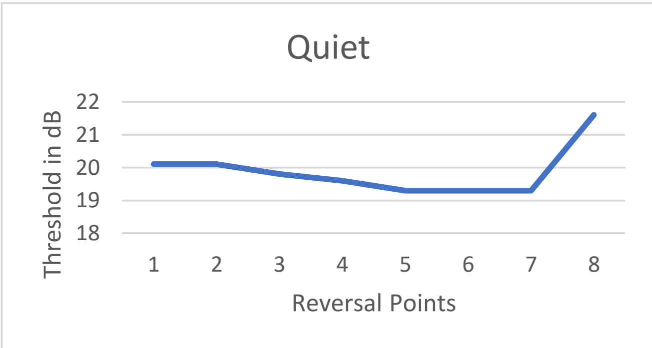
	SRT
Chi-Square	3.114
df	6
Asymp. Sig.	.794

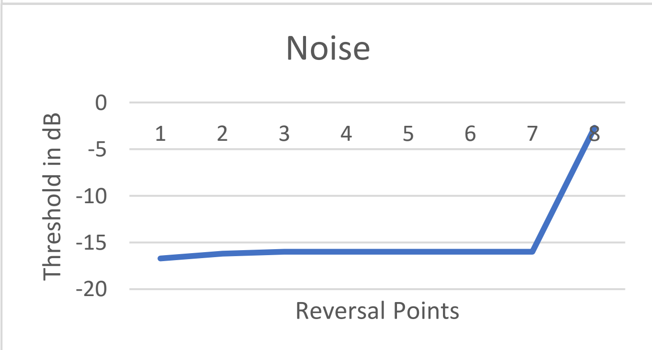
Test Statistics[a,b]

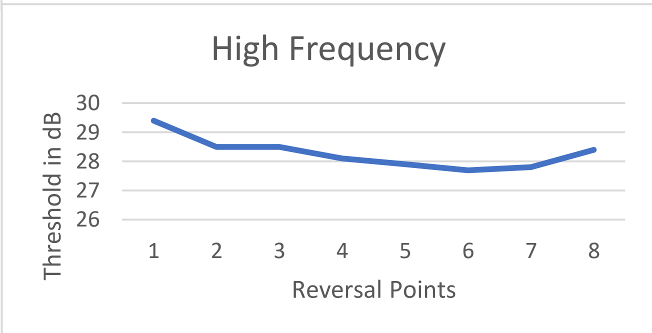
	SRT
Chi-Square	56.038
df	6
Asymp. Sig.	.000

Test Statistics[a,b]

	SRT
Chi-Square	.983
df	6
Asymp. Sig.	.986







Comparison across ages: