Developing a Hearing Screening Material for the Ghanaian Adult Population

Sesi Collins Akotey

A thesis submitted to the University of Ottawa
in partial fulfillment of the requirements for the
degree of Doctor in Philosophy in Rehabilitation Sciences

School of Rehabilitation Sciences
Faculty of Health Sciences
University of Ottawa

uOttawa

L'Université canadienne
Canada's university

General Abstract

Background: Hearing loss affects a significant number of people worldwide, with an estimated 1.5 billion people experiencing varying degrees of hearing impairment. Unfortunately, many hearing loss cases, especially in low- and -middle-income countries such as Ghana, go undetected and untreated. Early identification through a hearing screening protocol is a key first step to curbing the burden of hearing loss. While pure-tone audiometry remains a relevant hearing screening method, it is important to evaluate a person's speech perception, and self-perceived hearing difficulties during a screening program, as these reflect their practical hearing capabilities in everyday communication situations. Advancements in hearing screening tools, such as the automated Digit Triplet Test and self-reported hearing handicap questionnaires, offer a solution for early identification of hearing loss.

Objective: The general objective of this research was to develop hearing screening material for the adult Ghanaian population.

Methods and Results: The first part of this doctoral thesis provided a descriptive and analytic overview of the historical development of Audiology services in Ghana, including an examination of the available and geographical distribution of hearing-related services in the country. Results revealed the significant progress that has been made in improving access to hearing healthcare in Ghana, as well as some challenges such as financial constraints, uneven distribution of audiological facilities, under-resourced facilities, lack of a national policy on hearing health, and lack of coverage of audiological services under the National Health Insurance Scheme.

The second part of the thesis describes the different stages for the development of the translated and cross-culturally adapted version of the Revised Hearing Handicap Inventory Screening tool (RHHI-S; Cassarly et al., 2020), into Asante-Twi. The evaluation of the Asante-Twi version of the

RHHI-S was conducted with a sample comprising 50 individuals with normal hearing and revealed that this adapted version of the questionnaire shows high internal consistency, with a Cronbach's alpha coefficient of $\alpha = 0.936$. However, further psychometric properties (predictive validity, construct validity, concurrent validity, internal consistency, reliability, and test-retest reliability) of the Asante-Twi version of the RHHI-S must be assessed before its use for hearing screening. The third part of the thesis describes the different stages for the adaptation of the Digit Triplet Test (DTT; ref), into Asante-Twi and Ghanaian English. The development of the Ghanaian Digit Triplet Test (GDTT) included initial recording, optimization, and measures of the triplet lists. The evaluation showed high consistency across both languages, with their mean speech recognition thresholds (SRTs) being similar (-11.3 dB for the Asante-Twi, and -11.4 dB for the Ghanaian English, respectively). The statistical characteristics of each language version were comparable to findings from digit triplet tests developed in other languages or dialects.

The fourth part of the thesis presents the results of the validation study of the GDTT as a hearing screening tool for Ghanaian adults. Results indicated positive correlations between the Asante-Twi version of the RHHI-S scores and hearing thresholds, as well as a strong correlation between audiometric pure-tone averaged thresholds (PTA) and SRTs obtained by the GDTT. Moreover, the Receiver Operating Characteristics showed a high sensitivity of the GDTT across four cut-off points. Clinically, this implied that the GDTT can serve as an effective screening method for identifying hearing impairment, particularly in settings where traditional audiometric equipment may be limited or inaccessible.

Conclusion: This thesis presented and evaluated the first hearing screening material for the Ghanaian adult population, addressing the need for accessible, and culturally friendly tools for early identification of hearing loss. This was accomplished by adapting the RHHI-S into Asante-

Twi and developing and validating the Ghanaian Digit Triplet Test (GDTT) in both Asante-Twi and Ghanaian English. The outcome of this research work not only addressed the need for hearing screening materials but also contributed to advancing hearing screening tailored to the linguistic needs of the adult population in Ghana. This study holds promise for promoting the early identification of hearing loss and facilitating access to suitable interventions, ultimately improving the hearing health and overall quality of life for individuals within the Ghanaian population.

Dedication

To the memories of my parents (Lena and Francis) and my siblings (Wisdom and Prosper), all blessed memories.

My hope is built on nothing less
than Jesus' blood and righteousness.
I dare not trust the sweetest frame,
but wholly lean on Jesus' name.

Refrain
On Christ the solid rock I stand;
all other ground is sinking sand,
all other ground is sinking sand.

(Edward Mote, 1834)

Acknowledgement

I acknowledge the invaluable support and contributions of many individuals who played a crucial role in the successful completion of this thesis. To them I am truly grateful.

Foremost, I extend my deepest gratitude to my supervisor, Professor Josée Lagacé. You have not only been my strongest advocate but also a true inspiration throughout this journey. Your guidance and mentorship have imparted more knowledge than I can adequately credit you for, leaving a lasting impression on my academic and personal growth.

I would also like to extend my heartfelt thanks to the esteemed members of my Thesis Advisory Committee (TAC), Professor Christian Giguère, and Professor Katrine Sauvé-Schenk. Your unwavering support, invaluable advice, and generous provision of resources have been instrumental in the completion of this work. I consider myself fortunate to have been under your guidance.

Special mention must be made of the University of Education, Winneba, including the esteemed Vice Chancellor, my colleagues at the Department of Special Education, and staff of the Centre for Hearing and Speech Services. Your unflinching support throughout my doctoral studies have been instrumental in this journey. To Professor Samuel K. Hayford and Professor Yaw Nyadu Offei, thanks for your confidence in me and your regular counsel anytime I call on you.

I am also deeply thankful to the dedicated staff and interns of the Brobby Hearing Assessment Center in Kumasi, Hearing Assessment Center in Korle Bu, Accra, and the Center for Hearing and Speech Services in Winneba for their assistance during my data collection phases of my research.

My gratitude extends to my beloved siblings (Jesse, Henrietta, Monica, Vivian, Chris, and George), my parent-in-law, and my friends, Felix Ladeka, Eric Ador, Edward Adza, Godfred Agbakplor, Apolinaire Mupenzi, my roommates in Ottawa, and members of the Church of

Pentecost, Nepean - Ottawa, for their unwavering love and unflinching encouragement, which have been a source of motivation. Special mention of Dr. Mawuli Kofi Tay for his time and support during my data analysis.

Lastly, I reserve a special place in my heart for my loving wife, Mawufemor, and our cherished son, Woewoe. Your enduring support, encouragement and boundless love throughout my study period have been the cornerstone of my resilience. I recognize the scarifies you have made for this noble cause, and I deeply appreciate your commitment. Bless you all!!!

Table of Contents

General Abstract .... *ii*

Acknowledgement .... *vi*

Table of Contents .... *viii*

Table of Tables .... *xiii*

Table of Figures .... *xv*

CHAPTER 1 .... *1*

Introduction 1

Global hearing health overview 1

Hearing screening methodologies 2

The Ghanaian situation 7

Theoretical framework 11

Developing linguistically adapted hearing screening material for the Ghanaian adult population 14

Objectives of the study 16

General overview of the thesis 17

CHAPTER 2 .... *27*

Development of Audiology in Ghana: Past, Present, and Future *27*

The Context 29

Development of Audiology 29

Human Resource Development 30

Access to Audiological Services 33

Early Identification and Intervention 34

Challenges 35

Prospects 35

Conclusion 36

Acknowledgement 36

Declaration of Interest 37

Reference 38

CHAPTER 3 .... *40*

Translation and cross-cultural adaptation of the Revised Hearing Handicap Inventory Screening Tool into Asante-Twi *40*

Introduction 42

Materials and Methods 44

Preparation: 45

Forward Translation: 45

Merge Translation: 46

Back Translation: 46

Expert Committee Review: 48

Field Testing: 48

Cognitive Debriefing: 48

Pilot Testing: 49

Results 50

Discussion 51

Strengths and Limitations 52

Conclusion 53

Declaration of Interest 53

Acknowledgment 53

Reference 54

CHAPTER 4 .... *58*

Development and Evaluation of Ghanaian Digit Triplet Test in Asante-Twi and Ghanaian English *58*

Abstract 59

Introduction 60

Methodology 63

Speech Materials and Masking Noise 63

Test Interface and Calibration 65

Participants 66

Procedures and Results 67

Phase 1 – Optimization of the Digits 68

Phase 2 – Normative Data and List Equivalence 69

Conclusion 75

Acknowledgement.......... 76

Declaration of Interest.......... 76

Reference.......... 77

CHAPTER 5.......... 82

Validation of the Ghanaian Digit Triplet Test for Hearing Screening in Ghana.......... 82

Abstract.......... 83

Introduction.......... 84

Methods and materials.......... 88

Participants.......... 89

Hearing screening questionnaire.......... 89

Pure tone audiometry.......... 90

Validation measures of the GDTT.......... 90

Results.......... 91

Participants.......... 91

Correlation between the hearing measures.......... 96

Correlations between pure tone hearing thresholds and SRT obtained with the GDTT – diotic condition.......... 98

Correlations between pure tone hearing thresholds and the speech recognition thresholds obtained with the GDTT – antiphase condition.......... 101

Definition of hearing loss using Receiver Operating Characteristics (ROC) curves.......... 104

Discussion.......... 109

GDTT: Asante-Twi group.......... 109

GDTT: Ghanaian English group.......... 110

Connecting the results obtained in the study.......... 111

Limitation of the study.......... 112

Conclusion.......... 113

Declaration of interest.......... 114

Reference.......... 115

CHAPTER 6.......... 117

General Discussion.......... 117

Implementation the Ghanaian hearing screening program.......... 123

Conclusion 124
Reference 125
APPENDIX I *127*
Consent for Participation in Survey *127*
APPENDIX II *130*
Information and Consent Form *130*
APPENDIX III *133*
Information and Consent Form *133*
APPENDIX IV *136*
License to Adapt and Translate RHHI-S *136*
Wolters Kluwer Health Inc. Terms and Conditions *137*
APPENDIX V *141*
Information and Consent Form *141*
APPENDIX VI *144*
Ethics Approval *144*
APPENDIX VII *145*
Final version – Asante-Twi RHHI-S. *145*
APPENDIX VIII *146*
Forward Translation of RHHI-S into Target Language (GSRM-T1) *146*
APPENDIX IX *149*
Forward Translation into Target Language (GSRM-T2) *149*
APPENDIX X *151*
Merged Translation (T12) *151*
APPENDIX XI *152*
Backward Translation 1 (GSRM-BT1) *152*
APPENDIX XII *153*
Back Translation 2 – GSRM-BT2 ..... *153*
APPENDIX XIII *154*
Approval from Komfo Anokye Teaching Hospital *154*

APPENDIX XIV... *155*
Approval from Korle Bu Teaching Hospital...*155*
APPENDIX XV.. *156*
Approval from Centre for Hearing and Speech Services.. *156*

Table of Tables

CHAPTER 1

Table 1. Phonetic transcription of Akan consonants using International Phonetic Alphabet (IPA) symbols.. 10

Table 2. The Asante-Twi numerals/digits... 11

CHAPTER 2

Table 1. Regional distribution of employed audiologists.. 32

Table 2. Institutions offering training in Audiology.. 34

CHAPTER 3

Table 1. Sample demographics for field testing... 50

Table 2. Test-retest reliability of the Asante-Twi version..51

CHAPTER 4

Table 1. Participant characteristics.. 67

Table 2. Multiple comparisons of adaptive data of GDTT English list order using the Tukey HSD test...70

Table 3. Suggested normative values for the GDTT..74

CHAPTER 5

Table 1: Demographic statistics of participants... 91

Table 2: Descriptive statistics for Asante-Twi participants... 93

Table 3: Descriptive statistics for Ghanaian English participants.............................. 94

Table 4: Relationship between hearing threshold (pure tone average) of the best ear (0.5, 1, 2, 4 kHz), RHHI-S scores, diotic and antiphase SRTs...98

Table 5: Definition of hearing loss by diotic SRT – Ghanaian English group...........................104

Table 6: Definition of hearing loss by diotic SRT – Asante-Twi group......................................105

Table 7: Definition of hearing loss by antiphase SRT – Ghanaian English group..................... 106

Table 8: Definition of hearing loss by antiphase SRT – Asante-Twi group................................ 107

Table of Figures

CHAPTER 1

Figure 1. Akan vowel chart.. 9

Figure 2: Examples of the interaction between components of the ICF and its link to a situation of an adult presenting a moderate sensorineural hearing loss.. 14

CHAPTER 2

Figure 1: Distribution of audiology centers..31

CHAPTER 3

Figure 1. Stages of the translation and cross-cultural adaptation of the RHHI-S into the Asante-Twi language... 47

CHAPTER 4

Figure 1. Spectra of the 27 digits and speech noise (overlying) used in the GDTT......................65

Figure 2. Testing interface of the GDTT... 66

Figure 3. Psychometric functions for each list of the GDTT..72

CHAPTER 5

Figure 1:Testing interface of the GDTT..86

Figure 2: Set-up for GDTT testing.. 87

Figure 3: Relationship between GDTT diotic SRT and best ear PTA. (A). Diotic SRT, English and best ear PTA (0.5,1,2,4 kHz), (B) Diotic SRT, English and best ear PTA (0.5,1,2, kHz), (C) Diotic SRT, English and best ear PTA (1,2,4), (D) Diotic SRT, Asante-Twi and best ear PTA (0.5,1,2,4 kHz), (E) Diotic SRT, Asante-Twi and best ear PTA (0.5,1,2 kHz), (F) Diotic SRT, Asante-Twi and best ear PTA (1,2,4 kHz)... 100

Figure 4: Relationship between GDTT antiphase SRT and best ear PTA. (A). Antiphase SRT, English and best ear PTA (0.5,1,2,4 kHz), (B) Antiphase SRT, English and best ear PTA (0.5,1,2,

kHz), (C) Antiphase SRT, English and best ear PTA (1,2,4), (D) Antiphase SRT, Asante-Twi and best ear PTA (0.5,1,2,4 kHz), (E) Antiphase SRT, Asante-Twi and best ear PTA (0.5,1,2 kHz), (F) Antiphase SRT, Asante-Twi and best ear PTA (1,2,4 kHz)..103

Figure 5: ROC curves presenting test characteristics for diotic GDTT SRT for detecting hearing threshold PTA – best ear (A) >25 dB HL, (B) >30 dB HL, (C) >35 dB HL, and (D) >40 dB HL. 105

Figure 6: ROC curves presenting test characteristics for antiphase GDTT SRT for detecting hearing threshold PTA – best ear (A) >25 dB HL, (B) >30 dB HL, (C) >35 dB HL, and (D) >40 dB HL...108

CHAPTER 1

Introduction

Hearing is a vital and fundamental component of intrinsic human capacity. The ability to perceive and understand sound is essential to the human experience. Through hearing, individuals actively engage in social interactions, receive auditory information, and navigate their environment. Therefore, any untreated reduction in hearing can have significant consequences for an individual's life (Louw et al., 2018). For the adult population, the impact can be wide and varied, including depression, social isolation, dementia, cognitive decline, reduced interpersonal communication, and reduced quality of life (Huddle et al., 2017; Lin et al., 2011; Livingston et al., 2020; Sarant et al., 2020).

Global hearing health overview

Globally, 1.5 billion people experience hearing loss, of which 430 million would require hearing care (World Health Organization, 2021a, 2021b). Although hearing loss is widespread, only a minority of cases, particularly in low- and middle-income countries (LMICs), are identified and provided with treatment. This is especially notable as the prevalence of hearing loss is higher in LMICs compared to high-income countries (Stevens et al., 2013). Specifically, hearing loss is more common in sub-Saharan Africa than in richer parts of the world (Mulwafu et al., 2016, 2017). In 2019, the economic impact of unidentified or unaddressed hearing loss globally amounted to approximately 981 billion American dollars annually (McDaid et al., 2021; World Health Organization, 2021b). The high cost and wide spread of hearing loss draw attention to the need for increased access to care (Louw et al., 2018; Ramkissoon & Cole, 2011). Early identification and appropriate management are vital in mitigating the consequences of hearing loss and preserving the hearing and quality of life of affected persons (Davis et al., 2007; Karpa et al., 2010; Olusanya, 2015; World Health Organization, 2021a). Implementing early identification programs through successful hearing screening in real-world settings remains a challenge, but innovative hearing screening strategies could expand access to care, ease the burden on primary healthcare systems, and ultimately lessen the economic impact of untreated hearing loss (Borre et al., 2023).

Hearing screening at regular intervals is necessary for the early identification of hearing loss, as hearing impairment can develop at any stage of life. Regular screenings, regardless of the age group, have the potential to raise awareness about hearing loss and generate behaviour change (Saunders et al., 2019). However, hearing screening remains suboptimal or virtually unavailable in sub-Saharan Africa (Mulwafu et al., 2016, 2017). This shortfall has been attributed to several factors. For example, there is a large shortage of trained professionals who can provide hearing assessment and on-going support in many LMICs (Fagan & Jacobs, 2009; Olusanya et al., 2014). More specifically, there are fewer than one audiologist per 100,000 inhabitants in sub-Saharan Africa (Mulwafu et al., 2017). Aside from human resources, the high cost of audiological equipment for hearing assessment significantly limits accessibility (Swanepoel et al., 2010). Overcoming these barriers through alternative screening methods is vital for implementing effective hearing screening protocols, especially in resource-limited settings.

Hearing screening methodologies

Selecting the most appropriate hearing screening test for a given population is vital (Denys et al., 2019). For the adult population, hearing screening can be conducted with different methods or techniques. The first is the use of a questionnaire to inquire about the person's hearing status and experiences of hearing difficulties in daily life (ASHA, n.d.). The use of validated questions supported by established psychometric properties is paramount for efficiency (Cassarly et al., 2020; Ventry & Weinstein, 1982; World Health Organization, 2021a). Self-reported hearing handicap questionnaires, such as the Hearing Handicap Inventory for the Elderly (HHIE; Ventry & Weinstein, 1982), the Hearing Handicap Inventory for Adults (HHIA; Newman et al., 1990), and the Speech, Spatial, and Quality of Hearing Scale (SSQ; Gatehouse & Noble, 2004), are valuable for assessing patients' perceived hearing difficulties and satisfaction with rehabilitation outcomes. These tools capture real-world auditory experiences that are often not reflected in standard clinical measures like pure tone audiometry. However, the choice of a self-report measure depends on factors such as the target age group, the domains of hearing to be assessed, and the context of use.

The Hearing Handicap Inventory for the Elderly (HHIE) and the Hearing Handicap Inventory for Adults (HHIA) are similar tools designed to measure the psychosocial impact of hearing loss, with both containing 25 items divided into emotional (13 items) and social/situational (12 items) subscales. They share the same scoring system. However, their primary difference lies in the target population and content focus. The HHIE is tailored for older adults (typically aged 65+), addressing challenges associated with aging, while the HHIA targets younger, working-age adults (Newman et al., 1990; Ventry & Weinstein, 1982). Additionally, the HHIE/HHIA, with its three-point response format (“yes,” “no,” and “sometimes”), is easy for patients to complete and quick for clinicians to analyze. Compared to SSQ, the HHIE/HHIA stands out as a robust tool to address both the social and emotional impacts of hearing difficulties. With its three-point response format (“yes,” “no,” and “sometimes”) (Newman et al., 1990; Ventry & Weiinstein, 1982), the HHIE/HHIA is easy to complete and quick to analyze. Furthermore, unlike the SSQ, which requires up to 49 items for the full version and focuses extensively on spatial hearing abilities, the HHIE/HHIA is concise, allowing it to be administered efficiently in both clinical and screening settings.

The Revised Hearing Handicap Inventory and Screening Tool (RHHI-S; Cassarly et al., 2020) is an adapted version of the HHIE and HHIA questionnaires for hearing screening purposes for adults of all ages (Cassarly et al., 2020). Each item of the RHHI-S can be answered with “No,” “Sometimes,” or “Yes,” corresponding to a specific score: 0 for “No,” 2 for “Sometimes,” and 4 for “Yes.” The total score over the 10 can be compared to a scale of hearing handicap, ranging from 0 (“no handicap”) to 40 (“maximum handicap”), or used to identify individuals at risk of hearing loss. According to the authors, a score between 0 and 8 suggests “no hearing handicap” or a 13% probability of hearing impairment, while a score between 10 and 24 points implies a 50% probability of hearing impairment. Finally, a score between 26 and 40 points indicates an 84% probability of hearing impairment (Cassarly et al., 2020). A cut-off of ≥6 is recommended for screening purposes to detect hearing loss (Cassarly et al., 2020).

Self-reported measures are relatively time-efficient in their administration and have been positively linked with help-seeking among adults (Knudsen et al., 2010). While there are several self-reported tools for hearing screening, the HHIA/HHIE remains one of the most widely used for adults due to its established validity (Cassarly et al., 2020).

A second approach to adult screening is to identify signs of hearing loss using pure tone audiometry, speech-in-noise tests, or other tools (World Health Organization, 2021b). Pure tone audiometry involves the use of tones presented at different frequencies and levels to measure the person’s ability to hear. However, pure tone audiometry presents technical specifications that can be challenging to meet in some screening settings. Barriers include the availability of a well-calibrated audiometer, qualified test administrators, conducive test environments with adequate acoustical treatment (Jansen et al., 2014; Oremule et al., 2024), and sufficient time to determine accurate and reliable responses. Normal or passing results obtained with pure tone audiometry screening tests do not necessarily mean the absence of pathology in the cochlear or central auditory system (Liberman et al., 2016; Pienkowski, 2017; Zadeh et al., 2019). Research indicates that 5 to 37% of adults with hearing thresholds within the normal range self-report hearing difficulties (Kennedy et al., 2006; Tremblay et al., 2015). It has been reported that pure tone audiometric results do not accurately predict the extent of difficulty an individual may encounter when attempting to comprehend speech in a demanding auditory setting, for example (Moore et al., 2017; Moore et al., 2014; Vermiglio et al., 2012). These limitations are especially relevant for adults who may exhibit pure tone audiometric thresholds within the normal range but still experience difficulties in challenging listening conditions.

Speech-in-noise tests are an alternative to pure tone screening techniques. They allow the identification of hearing loss and hearing difficulties (Jansen et al., 2010; Smits et al., 2004; Smits & Houtgast, 2006) and do not require strict quiet conditions for their use. In recent years, the Digit Triplet Test (DTT, Smits et al., 2004) has shown promise in increasing access to hearing screening and early identification of hearing loss (De Sousa et al., 2019). The DTT, originally developed in the Dutch language (Smits et al., 2004), has demonstrated robustness, validity, and reliability as a hearing screening tool (Akeroyd et al., 2015; Denys et al., 2019; Wilson et al., 2005). The DTT utilizes randomized digit triplets spoken to assess speech intelligibility. Digits are familiar words and are among the first words to be acquired in a language, even for second-language speakers with limited linguistic knowledge (Giguère et al., 2020; Smits et al., 2013). During testing, the DTT imposes minimal memory load on participants during triplet recall (Giguère et al., 2020; Smits et al., 2004), making it a reliable estimator of hearing sensitivity (Jansen et al., 2013; Smits et al., 2013). Additionally, the DTT excels in its adaptability to noisy environments, making it an excellent test for a high-quality hearing screening test with a high test-retest reliability, sensitivity, and specificity and a strong correlation with average pure tone thresholds (Smits et al., 2004; Van den Borre et al., 2021).

The DTT has been adapted into several languages (Van den Borre et al., 2021), including various English versions like Canadian English (Giguère et al., 2020) and South African English (Potgieter et al., 2016). It can be administered as a rapid, fully automated self-test accessible through different platforms such as the telephone, smartphones, computers, and internet (Folmer et al., 2017; Potgieter et al., 2016, 2018; Smits et al., 2004; Van den Borre et al., 2021), without requiring an acoustically treated environment or other clinical equipment (Mahomed-Asmail et al., 2016; Summers et al., 2013; Swanepoel et al., 2014; Vlaming et al., 2014). In a bid to enhance standardization and comparability of the DTT test properties across languages and countries, the International Collegium of Rehabilitative Audiology (ICRA) outlined a blueprint for the development of the DTT (Akeroyd et al., 2015). This blueprint serves as an important resource for researchers to provide a structured approach to test development, resulting in the creation of the DTT in several languages with various modifications.

Due to the successful implementation of the DTT for hearing screening, efforts have been made to enhance the test's efficiency by experimenting with modifications to achieve a wider spread of Speech Recognition Thresholds (SRTs) among participants (Denys et al., 2019). Alternatives such as different maskers and low-pass filters have been explored. Vlaming et al. (2014) investigated the use of low-pass noise filters to improve sensitivity to high-frequency hearing loss in the digit in noise test. They reported improved sensitivity and specificity for high-frequency hearing loss using low-pass filter noise compared with broadband noise, with a strong correlation between SRTs obtained using the low-pass filtered digit-in-noise test and the pure tone average of participants with high-frequency hearing loss. Smits (2017) demonstrated a fixed signal-to-noise ratio (SNR) procedure that could reduce the number of digit triplets to eight trials without compromising sensitivity and specificity. Denys et al. (2019) investigated the effect of low-pass filtered noise on test-retest reliability and whether the digit scoring procedure would increase test-retest reliability compared with baseline DTT with broadband speech-shaped noise. They concluded that using low-pass filtered noise did not improve SRT-PTA correlation or increase reliability. De Sousa et al. (2021) investigated the predictors and normative ranges of both the antiphase and diotic digit-in-noise test to determine whether a combination of these diotic tests could more accurately categorize hearing. They concluded that the antiphase digit-in-noise test was a superior screening tool compared to the diotic digit-in-noise test for detecting various types of hearing loss (De Sousa et al., 2020). These studies highlight the ongoing advancements in refining hearing screening methods, emphasizing the need for further research to optimize test accuracy and reliability.

As the field of hearing assessments expands its test battery, screening for hearing loss and speech recognition ability should not be limited to performance measurements alone. A comprehensive hearing screening material should include the two stages of adult hearing screening as recommended by the World Health Organization (2021b), specifically the identification of self-perceived or self-reported signs of hearing loss in daily life using validated questionnaires (such as the RHHI-S) and behavioural measures such as the use of a digit triplet test.

The Ghanaian situation

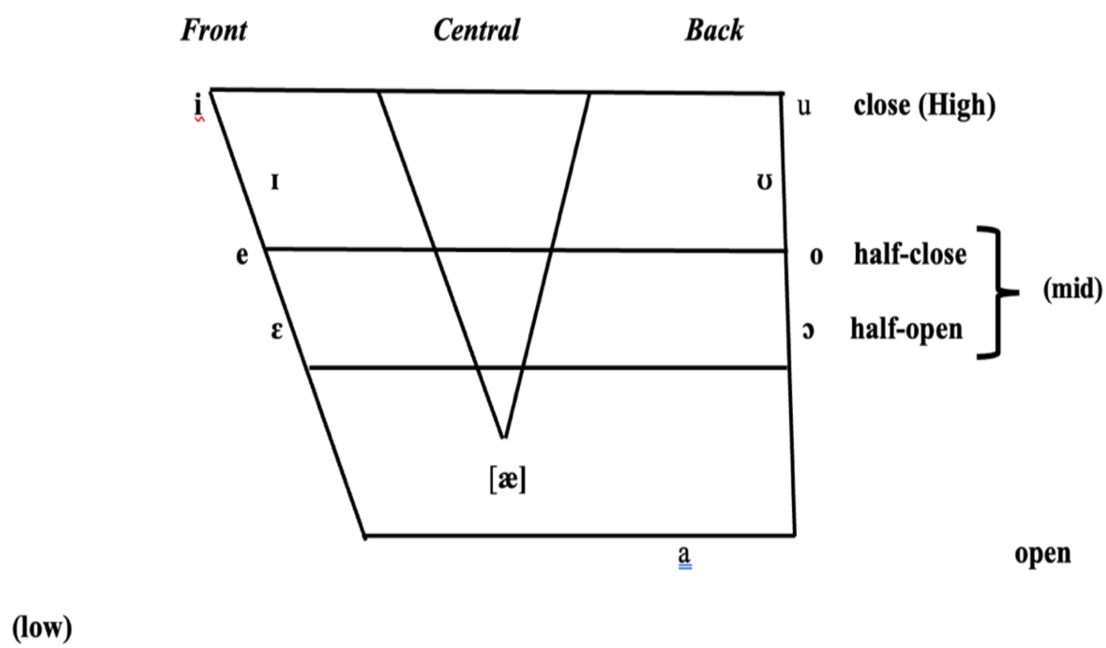
Ghana is a multilingual and multiethnic country with a diverse linguistic landscape. English serves as the language for all official communication and education (Agbozo, 2015; Da-Costa et al., 2019) and is spoken by over 96% of those aged six and above who attend school (Ghana Statistical Service, 2021). However, English in Ghana has developed uniquely, blending local linguistic and cultural influences, affecting vocabulary, pronunciation, and idiomatic expressions (Adika, 2012). In addition to English, there are over seventy indigenous languages (Appiah & Ardila, 2020). Among these indigenous languages, Akan (Asante-Twi) is the most widely spoken language. Akan, belonging to the Kwa (Niger-Congo) language, is predominantly spoken in the southern half of Ghana (Appah, 2013; Paster, 2011) and is present and spoken in all sixteen administrative regions of Ghana (Ghana Statistical Service, 2021).

In Ghana, like many other countries, hearing loss affects a significant portion of the population, with a prevalence of hearing loss of 16.8% among rural dwellers and 12.9% among urban dwellers of all ages (Ghana Statistical Service, 2013). Despite access to quality health care being a fundamental human right, many individuals with hearing loss in Ghana face significant barriers to hearing services (Adadey et al., 2020). Notably, only 10% of the population has access to hearing services (Offei, 2017). This situation is primarily due to the uneven distribution of hearing care facilities, financial barriers, and assessment tools (Adadey et al., 2020; Offei, 2017). Early identification of hearing loss through screening is an essential step in bridging these gaps, as it enables timely intervention and can significantly improve outcomes for affected individuals.

While hearing screening questionnaires and digits-in-noise tests are available in various languages (Laohasiriwong et al., 2018; Thammaiah et al., 2016; Van den Borre et al., 2021), none is available in any Ghanaian language. Offei (2017) reported the absence of national hearing programs and protocols for early identification of hearing loss in Ghana. An easily accessible, point-of-care hearing screening material for the adult population in Ghana is essential for improving early identification of hearing loss. In screening for hearing loss and assessing rehabilitation needs, the use of a language-based test in the listener’s native language is very important (Zokoll et al., 2013). The Ghanaian hearing screening material should utilize Asante-Twi and Ghanaian English, ensuring that linguistic factors do not impact the screening process, thereby possibly enhancing the accuracy and effectiveness of the assessment.

Understanding the phonological characteristics (the vowel and consonant sounds) in Asante-Twi is essential for creating a linguistically appropriate tool. The phonology of Akan (Asante-Twi) is made up of 10 vowels: /i, ɪ, e, ɛ, a, æ, o, ɔ, u, ʊ/ (Figure 1) (Abakah, 2005, 2016; Dolphyne, 1988). These vowel sounds are orthographically represented as /a, e, ɛ, o, ɔ, u, i/. All front and central vowels in Akan are unrounded, and all back vowels are rounded.

Figure 1. Akan vowel chart



Note: A chart of Akan vowels in terms of the relative height and tongue positions (adapted from Abakah, 2013; Amoako 2020).

The phonetic representation of consonants in Akan (Asante-Twi) has been studied by several authors. Some authors have reported 8 consonants while others report 14 (Abakah, 2005, 2013, 2016; Amoako, 2020). The 14 consonant sets include [p/, /b/, /t/, /d/, /k/, /g/, /m/, /n/, /ɹ/, /f/, /s/,

/h/, /j/, /w/]. Additionally, certain consonant combinations are represented by two symbols, as observed in the initial consonants of words like ‘*gye’* meaning **‘**receive**’** and ‘*hwie’* meaning ‘pour out,**’** among others. Table 1 below represents the consonants found in Asante-Twi.

Table 1. Phonetic transcription of Akan consonants using International Phonetic Alphabet (IPA) symbols (adapted from Amoako, 2020; Dolphyne, 1988).

Place/ Manner	**Bila-bial**	**Labio-dental**	**Alveo-lar**	**Alveolo-Palatal**	**Palatal**	**Labio-palatal**	**Labio-velar**	**Velar**	**Glottal**
Stop	P b		t d					k g	
Affricate				**tɕ dʑ**					
Nasal	m		n		**ɲ**			**ŋ**	
Lateral			l						
Fricative		f	s	**ɕ**					h
Approximant/ Glide			ɹ		j	ɥ	w		

Table 2 below presents the Asante-Twi numerals (the first ten) by name with their standard IPA transcription and number of syllables.

Table 2. The Asante-Twi numerals/digits (adapted from Appah et al., 2023).

Numerals	**Name**	**Transcription**	**Syllables**
0	Hwee	/ ɕɥɪɪ /	Disyllabic (2)
1	Baako	/baakʊ /	Trisyllabic (3)
2	Mmienu	/mmʲienʷu/	Polysyllabic (4)
3	mmiɛnsa	/mmʲɪɛnsa/	Polysyllabic (5)
4	Nnan	/nnan/	Trisyllabic (3)
5	Nnum	/nnʷum/	Trisyllabic (3)
6	Nsia	/nsʲia/	Trisyllabic (3)
7	Nson	/nsʷʊn/	Trisyllabic (3)
8	nwɔtwe	/nnwɔʨɥɪ/	Trisyllabic (3)
9	Nkron	/nkrʷʊn/	Trisyllabic (3)

Theoretical framework

The framework chosen to underpin this study is the International Classification of Functioning, Disability, and Health (ICF) (World Health Organization, 2001). The ICF classification provides a unified and standardized language and framework for describing health and health-related states, offering a scientific basis for studying the outcomes and determinants (World Health Organization, 2001). This classification framework integrates the social and medical models of disability (World Health Organization, 2001), shifting towards a holistic understanding of health and well-being as interactions between health conditions and contextual factors. The framework shifted from classifying conditions as "consequences of disease" to viewing them as "components of health" (World Health Organization, 2001). "Components of health" are the constituents of health, whereas the "consequences" focus on the impacts or results of diseases or other health conditions. This holistic approach is particularly relevant for understanding the impact of hearing difficulties on individuals' overall well-being within the context of developing the Ghanaian hearing screening material.

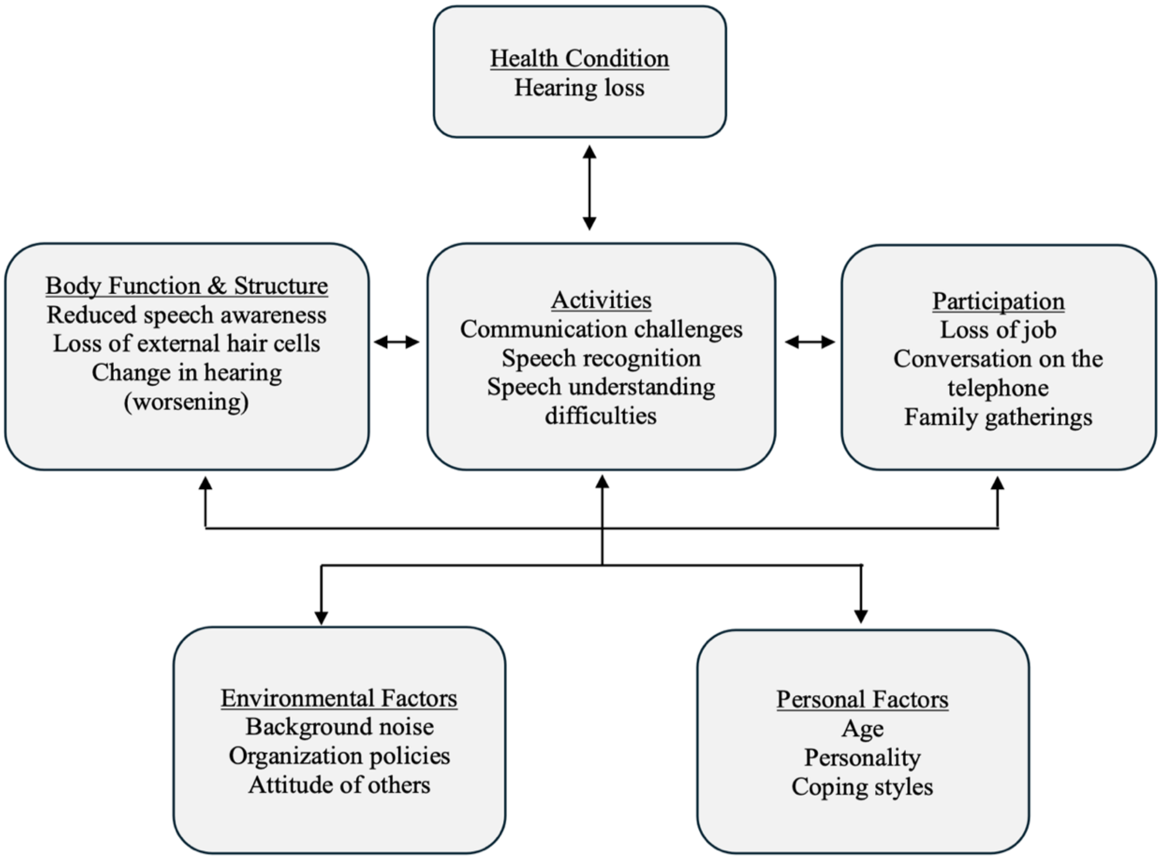
In the framework, impairment, activity limitations, participation restrictions, and a person’s experience of functioning and disability are different concepts. In the ICF framework, *functioning* encompasses all aspects of bodily functions, activities, and participation, while disability is a generic term for impairments, activity limitations, and participation restrictions (World Health Organization, 2001). Understanding the difference between *activity* and *participation* is vital within this framework. *Activity* refers to the execution of a task or action by an individual (World Health Organization, 2001). In relation to hearing, the *activity* refers to listening, perceiving sounds, and recognizing speech, for example. On the other hand, *participation* involves the broader impact of *function* and *activities* in life situations (World Health Organization, 2001). In relation to hearing, participation refers to communication, social engagement, access to education, and hearing awareness. Activity limitations refer to difficulties an individual may have in executing activities, whereas participation restrictions are problems an individual may experience in engaging in life situations (World Health Organization, 2001). An example of the different components of health that could influence the impact or consequences of a hearing loss, using the ICF framework, is represented in Figure 2. Moreover, the ICF emphasizes the influence of environmental factors, such as access to assessment facilities, noise or sound interference, communication support, societal attitudes, and acoustic characteristics of the environment, on an individual's functioning and disability.

The importance of considering the *personal* and *environmental factors* in shaping *functioning and disability* is emphasized in the ICF framework. Environmental factors interact with body functions (World Health Organization, 2001), as in the interaction between sounds and hearing. For instance, access to hearing assessment facilities, quality intervention services, and social support can significantly contribute to an individual's functional well-being, particularly in early hearing identification, intervention, and communication programs. Considering these factors is essential for tailoring the screening material to the Ghanaian context, where cultural beliefs, societal attitudes, a limited number of personnel and facilities, and environmental challenges can influence individuals' experiences with hearing difficulties.

The ICF classification is a also valuable framework for developing assessment tools to measure individual functioning. By conceptualizing the assessment process, the ICF assists in selecting the aspects of functioning and disability to be evaluated, recognizing the close link between an individual's functioning and underlying health condition (World Health Organization, 2001). This approach ensures that audiological assessments, including hearing screening processes, begin with an evaluation of some components within this framework: activity, participation, and environment. The hearing assessment (screening) involves gathering information not only about the individual's hearing function and structure but also about the impact of hearing difficulties on various aspects of their life, such as psychosocial well-being, communication, daily activities, and education or work. This approach enables an understanding of the challenges faced by individuals with hearing difficulties, complementing behavioural measures like speech perception tests with relevant contextual information.

By utilizing the ICF framework, healthcare professionals and researchers can provide descriptions of how hearing conditions impact various aspects of individuals' lives, including impairment, activity limitations, participations, and the contextual influences of environmental factors.

Figure 2: Examples of the interaction between components of the ICF and its link to a situation of an adult presenting a moderate sensorineural hearing loss (Adapted from World Health Organization, 2001).



Developing linguistically adapted hearing screening material for the Ghanaian adult population

In the context of the Ghanaian hearing screening material, the ICF framework informs the selection of screening tools and assessment measures that go beyond hearing loss alone. By incorporating activity, and participation-based indicators into the screening, such as assessing speech perception in real-world communication settings and identifying barriers to participation in social and work-related activities due to hearing difficulties, the protocol can provide a more meaningful and contextually relevant evaluation of individuals' hearing health.

In view of developing hearing screening material for the adult population of Ghana, this means having access to linguistically adapted tools, as well as considering the access to hearing healthcare services and the availability of intervention options. The screening material should account for these factors to ensure that the screening is relevant and effective in the local context.

The linguistic diversity in Ghana presents unique challenges and opportunities for developing effective hearing screening tools. The screening material also must be linguistically inclusive (Zokoll et al., 2013), as well as capable of assessing both the objective and subjective dimensions of hearing difficulties. A language-based hearing screening material available in the most widely spoken indigenous language, Asante-Twi, as well as in Ghanaian English, is essential. This dual language approach should facilitate broad access to hearing screening services, accommodating those who may be more comfortable with the indigenous language as well as those proficient in English.

This study addresses this need by proposing the development of the Ghanaian Digit Triplet Test (GDTT) in both Asante-Twi and Ghanaian English and translating and cross-culturally adapting the Revised Hearing Handicap Inventory Screening Tool (RHHI-S) into Asante-Twi for hearing screening purposes. The GDTT will offer an automated and self-administered screening option that can overcome the technical and logistical challenges associated with traditional pure-tone audiometry. This test will allow individuals to assess their hearing abilities in a user-friendly manner, without the need for specialized equipment or extensive training.

In addition, the translation and cross-cultural adaptation of the RHHI-S into Asante-Twi will provide a culturally relevant tool to subjectively assess perceived hearing difficulties. This tool will enable hearing healthcare providers to better understand the impact of hearing difficulties on the daily lives of Ghanaian adults, facilitating early identification and possibly appropriate intervention strategies. By addressing both objective and subjective measures of hearing, this dual approach enhances the comprehensiveness of hearing screening in Ghana, ultimately contributing to improving hearing health outcomes across the country. This position is further strengthened by the ICF framework as it highlights that the same hearing assessment results (hearing thresholds) can lead to different RHHI-S scores in different individuals.

Objectives of the study

The general objective of the thesis was to develop hearing screening materials for the adult Ghanaian population. This was preceded by a literature review to understand the current state of hearing health in Ghana.

The first specific objective was to translate and adapt the Revise Hearing Handicap Inventory Screening Tool (RHHI-S; Cassarly et al. 2020) into Asante-Twi by following the seven stages of translation and cross-cultural adaptation from Hall et al. (2018). The translated and adapted RHHI-S was evaluated on participants in Ghana.

The second objective was to develop the Ghanaian digit triplet test (GDTT) using digit tokens in Asante-Twi and Ghanaian English. The digits were recorded with a native female speaker of Asante-Twi and Ghanaian English. The digit triplets were optimized, the equivalency of the test lists evaluated, and test norms established.

This project's third objective was to validate the GDTT and the screening material, which followed a two-stage process. This process included multi-site testing, including Ghanaian adult participants with varying levels of hearing sensitivity and functioning, using the GDTT, the adapted RHHI-S, and pure tone audiometry.

General overview of the thesis

This doctoral thesis includes a series of four articles, constituting Chapters 2 through 5. Each chapter stands alone as an article, formatted for publication in a peer-reviewed journal.

More specifically, Chapter 2 presents a comprehensive overview of the historical development in Ghana, highlighting key successes, ongoing challenges, and prospects for the field. This article, “Development of Audiology in Ghana: Past, Present, and Future” was published in the International Journal of Audiology, 2023 (DOI: 10.1080/14992027.2023.2263813).

Chapter 3 details the cross-cultural adaptation and translation of the Revised Hearing Handicap Inventory Screen Tool (RHHI-S) into Asante-Twi, the most widely spoken indigenous language in Ghana, ensuring its relevance and applicability within the local context. This article, “Translation and cross-cultural adaptation of the Revised Hearing Handicap Inventory Screening Tool into Asante-Twi,” has been published in the HSOA Otolaryngology Head and Neck Surgery journal, 2024 (10: 087 DOI: 10.24966/OHNS-010X/100087).

Chapter 4 describes the methodological process involved in the development and evaluation of the Ghanaian Digit Triplet Test (GDTT), a novel screening tool for adults. The test, available in both Asante-Twi and Ghanaian English, was developed at the Hearing Research Laboratory, University of Ottawa, and was evaluated at the Centre for Hearing and Speech Services (CHSS), University of Education, Winneba, Ghana. The article, “Development and evaluation of the Ghanaian digit triplet test in Asante-Twi and Ghanaian English,” has been submitted to the International Journal of Audiology, 2024.

Chapter 5 presents the validation processes and results of the GDTT, comparing its outcomes with pure tone audiometric thresholds and participants’ scores on the RHHI-S. This validation study was conducted in a multi-site study at three facilities in Ghana, providing robust data on the test’s effectiveness. The resulting article, "Validation of the Ghanaian digit triplet test for hearing screening in Ghana," will be submitted to the Ear and Hearing Journal.

Chapter 6 includes a discussion of the different findings of the studies that were conducted for this doctoral thesis (reported in Chapters 2, 3, 4, and 5) as well as the clinical implications and the conclusion. Directions for further research are also included in Chapter 6.

Reference

Abakah, E. N. (2005). Phonological analysis of word-final consonants in Akan. *Africa*, *5*, 47–65.

Abakah, E. N. (2013). Vowel replacement patterns in the Mfantse dialect of Akan. *Journal of Universal Language*, *14*(2), 7–51.

Abakah, E. N. (2016). Hypotheses on the diachronic development of the Akan language group1. *Journal of Universal Language*, *17*(1), 1–51. https://doi.org/10.22425/jul.2016.17.1.1

Adadey, S. M., Quaye, O., Amedofu, G. K., Awandare, G. A., & Wonkam, A. (2020). Screening for GJB2-R143W-associated hearing impairment: Implications for health policy and practice in Ghana. *Public Health Genomics*, *7925*. https://doi.org/10.1159/000512121

Adika, G. S. K. (2012). English in Ghana: Growth, tensions, and trends. *International Journal of Language, Translation and Intercultural Communication*, *1*, 151. https://doi.org/10.12681/ijltic.17

Agbozo, G. E. (2015). *Language choice in Ghanaian classrooms: Linguistic realities and perceptions*. Norwegian University of Science and Technology.

Akeroyd, M. A., Arlinger, S., Bentler, R. A., Boothroyd, A., Dillier, N., Dreschler, W. A., Gagné, J. P., Lutman, M., Wouters, J., Wong, L., & Kollmeier, B. (2015). International Collegium of Rehabilitative Audiology (ICRA) recommendations for the construction of multilingual speech tests. *International Journal of Audiology*, *54*, 17–22. https://doi.org/10.3109/14992027.2015.1030513

American Speech-Language-Hearing Association (n.d.). *Adult Hearing Screening* (Practice Portal). Retrieved month, day, year, from www.asha.org/Practice-Portal/Professional-Issues/Adult-Hearing-Screening/

Amoako, W. K. (2020). *Assessing phonological development among Akan-speaking children*. University of British Columbia.

Appah, C. K. I. (2013). *Construction morphology: Issues in Akan complex nominal morphology* [Doctoral thesis]. Lancaster University.

Appah, C. K. I., Duah, R. A., & Kambon, O. B. (2023). Cardinal numerals in Akan. *Ghana Journal of Linguistics*, *12*(1), 48–72. https://doi.org/10.4314/gjl.v12i1.3

Appiah, S. O., & Ardila, A. (2020). The question of school language in multilingual societies: The example of Ghana. *RUDN Journal of Psychology and Pedagogics*, *17*(2), 263–272. https://doi.org/10.22363/2313-1683-2020-17-2-263-272

Borre, E. D., Dubno, J. R., Myers, E. R., Emmett, S. D., Pavon, J. M., Francis, H. W., Ogbuoji, O., & Sanders Schmidler, G. D. (2023). Model-projected cost-effectiveness of adult hearing screening in the USA. *Journal of General Internal Medicine*, *38*(4), 978–985. https://doi.org/10.1007/s11606-022-07735-7

Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The revised hearing handicap inventory and screening tool based on psychometric reevaluation of the hearing handicap inventories for the elderly and adults. *Ear and Hearing*, *41*(1), 95–105. https://doi.org/10.1097/AUD.0000000000000746

Da-Costa, A., Caroline, C., Yeboah, A.-, & Asuamah, A. (2019). Language practice and the dilemma of a national language policy in Ghana: The past, present and future. *International Journal of Humanities and Social Science*, *9*(3), 142–149. https://doi.org/10.30845/ijhss.v9n3p18

Davis, A., Smith, P., Ferguson, M., Stephens, D., & Gianopoulos, I. (2007). Acceptability, benefit and costs of early screening for hearing disability: A study of potential screening tests and models. *Health Technology Assessment*, *11*(42). http://www.hta.ac.uk

De Sousa, K. C., Swanepoel, D. W., Moore, D. R., Myburgh, H. C., & Smits, C. (2020). Improving sensitivity of the digit-in-noise test using antiphasic stimuli. *Ear & Hearing*, *41*, 442–450.

De Sousa K, C., Swanepoel De Wet, Moore D., R., Myburgh H., C., & Smits Cas. (2019). Improving sensitivity of the digits-in-noise test using antiphasic stimuli. *Ear & Hearing*, *41*(2), 442–450.

Denys, S., Hofmann, M., van Wieringen, A., & Wouters, J. (2019). Improving the efficiency of the digit triplet test using digit scoring with variable adaptive step sizes. *International Journal of Audiology*, *58*(10), 670–677. https://doi.org/10.1080/14992027.2019.1622042

Dolphyne, F. A. (1988). *The Akan (Twi-Fante) language: its sound systems and tonal structure.* Accra: Ghana Universities Press.

Fagan, J. J., & Jacobs, M. (2009). Survey of ENT services in Africa: Need for a comprehensive intervention. *Global Health Action*, *2*(1), 1–7. https://doi.org/10.3402/gha.v2i0.1932

Folmer, R. L., Vachhani, J., McMillan, G. P., Watson, C., Kidd, G. R., & Patrick, F. M. (2017). Validation of a computer-administered version of the digit-in-boise test for hearing screening in the United States. *J Am Acad Audiol.*, *28*(2), 161–169. https://doi.org/10.3766/jaaa.16038

Gatehouse, S., & Noble, I. (2004). The Speech, Spatial and Qualities of Hearing Scale (SSQ). *International Journal of Audiology*, *43*(2), 85–99. https://doi.org/10.1080/14992020400050014

Ghana Statistical Service (GSS). (2013). 2010 population & housing census national analytical report. *Ghana Statistical Service*, 1–91.

Ghana Statistical Service (GSS). (2021). *Ghana 2021 population and housing census - General report volume 3D: Literacy and education* (Vol. 3D). https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3D_Literacy and Education.pdf

Giguère, C., Lagacé, J., Ellaham, N. N., Pichora-Fuller, M. K., Goy, H., Bégin, C., Alary, É., & Bowman, R. (2020). Development of the Canadian digit triplet test in English and French. *The Journal of the Acoustical Society of America*, *147*(3), EL252–EL258. https://doi.org/10.1121/10.0000825

Hall, D. A., Zaragoza Domingo, S., Hamdache, L. Z., Manchaiah, V., Thammaiah, S., Evans, C., & Wong, L. L. N. (2018). A good practice guide for translating and adapting hearing-related questionnaires for different languages and cultures. *International Journal of Audiology*, *57*(3), 161–175. https://doi.org/10.1080/14992027.2017.1393565

Huddle, M. G., Goman, A. M., Kernizan, F. C., Foley, D. M., Price, C., Frick, K. D., & Lin, F. R. (2017). The economic impact of adult hearing loss: A systematic review. In *JAMA Otolaryngology - Head and Neck Surgery* (Vol. 143, Issue 10, pp. 1040–1048). American Medical Association. https://doi.org/10.1001/jamaoto.2017.1243

Jansen, S., Luts, H., Dejonckere, P., Van Wieringen, A., & Wouters, J. (2013). Efficient hearing screening in noise-exposed listeners using the digit triplet test. *Ear and Hearing*, *34*(6), 773–778. https://doi.org/10.1097/AUD.0b013e318297920b

Jansen, S., Luts, H., Dejonckere, P., Van Wieringen, A., & Wouters, J. (2014). Exploring the sensitivity of speech-in-noise tests for noise-induced hearing loss. *International Journal of Audiology*, *53*(3), 199–205. https://doi.org/10.3109/14992027.2013.849361

Jansen, S., Luts, H., Wagener, K. C., Frachet, B., & Wouters, J. (2010). The French digit triplet test: A hearing screening tool for speech intelligibility in noise. *International Journal of Audiology*, *49*(5), 378–387. https://doi.org/10.3109/14992020903431272

Karpa, M. J., Gopinath, B., Beath, K., Rochtchina, E., Cumming, R. G., Wang, J. J., & Mitchell, P. (2010). Associations between hearing impairment and mortality risk in older persons: The blue mountains hearing study. *Annals of Epidemiology*, *20*(6), 452–459. https://doi.org/10.1016/j.annepidem.2010.03.011

Kennedy, V., Wilson, C., & Stephens, D. (2006). *When a normal hearing test is just the beginning*. 417–420.

Knudsen, V. L., Öberg, M., Nielsen, C., Naylor, G., & Kramer, S. E. (2010). Factors influencing help seeking, hearing aid uptake, hearing aid use and satisfaction with hearing aids: A review of the literature. *Trends in Amplification*, *14*(3), 127–154. https://doi.org/10.1177/1084713810385712

Laohasiriwong, S., Kasemsiri, P., Thanavirathananich, P., & Yimtae, K. (2018). Validity and test-retest reliability of hearing handicap inventory for the elderly Thai version (HHIE-Thai). *Annals of Otolaryngology and Rhinology*, *5*(1), 1204.

Liberman, M. C., Epstein, M. J., Cleveland, S. S., Wang, H., & Maison, S. F. (2016). Toward a differential diagnosis of hidden hearing loss in humans. *PLoS ONE*, *11*(9). https://doi.org/10.1371/journal.pone.0162726

Lin, F. R., Metter, E. J., O'brien, R. J., Resnick, S. M., Zonderman, A. B., & Ferrucci, L. (2011). Hearing loss and incident dementia. *Arch Neurol*, *68*(2), 214–220. http://www.r-project

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., Cooper, C., Costafreda, S. G., Dias, A., Fox, N., Gitlin, L. N., Howard, R., Kales, H. C., Kivimäki, M., Larson, E. B., Ogunniyi, A., … Mukadam, N. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet commission. In *The Lancet* (Vol. 396, Issue 10248, pp. 413–446). Lancet Publishing Group. https://doi.org/10.1016/S0140-6736(20)30367-6

Louw, C., Swanepoel, D. W., & Eikelboom, R. H. (2018). Self-reported hearing loss and pure tone audiometry for screening in primary health care clinics. *Journal of Primary Care and Community Health*, *9*, 0–7. https://doi.org/10.1177/2150132718803156

Mahomed-Asmail, F., Swanepoel, D. W., Eikelboom, R. H., Myburgh, H. C., & Hall, J. (2016). Clinical validity of hearScreenTM smartphone hearing screening for school children. *Ear and Hearing*, *37*(1), e11–e17. https://doi.org/10.1097/AUD.0000000000000223

McDaid, D., Park, A. La, & Chadha, S. (2021). Estimating the global costs of hearing loss. *International Journal of Audiology*, *60*(3), 162–170. https://doi.org/10.1080/14992027.2021.1883197

Moore, D., Hunter, L., & Munro, K. (2017). Benefits of extended high-frequency audiometry for everyone. *Hearing Journal*, *70*(3), 4–6. https://doi.org/10.1097/01.HJ.0000513797.74922.42

Moore, D. R., Edmondson-Jones, M., Dawes, P., Fortnum, H., McCormack, A., Pierzycki, R. H., & Munro, K. J. (2014). Relation between speech-in-noise threshold, hearing loss and cognition from 40-69 years of age. *PLoS ONE*, *9*(9). https://doi.org/10.1371/journal.pone.0107720

Mulwafu, W., Ensink, R., Kuper, H., & Fagan, J. (2017). Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015. *Global Health Action*, *10*(1). https://doi.org/10.1080/16549716.2017.1289736

Mulwafu, W., Kuper, H., & Ensink, R. J. H. (2016). Prevalence and causes of hearing impairment in Africa. *Tropical Medicine and International Health*, *21*(2), 158–165. https://doi.org/10.1111/tmi.12640

Newman, C. W., Weinstein, B. E., Jacobson, G. P., & Hug, G. A. (1990). The hearing handicap inventory for adults: Psychometric adequacy and audiometric correlates. *Ear and Hearing*, *11*(6), 430–433. https://doi.org/10.1097/00003446-199012000-00004

Offei, Y. N. (2017). Audiology in Ghana. *Global Audiology*, 1–6.

Olusanya, B. O. (2015). Screening for neonatal deafness in resource-poor countries: Challenges and solutions. *Research and Reports in Neonatology*, 51. https://doi.org/10.2147/rrn.s61862

Olusanya, B. O., Neumann, K. J., & Saunders, J. E. (2014). The global burden of disabling hearing impairment: A call to action. *Bulletin of the World Health Organization*, *92*(5), 367–373. https://doi.org/10.2471/BLT.13.128728

Oremule, B., Abbas, J., Saunders, G., Kluk, K., Isba, R., Bate, S., & Bruce, I. (2024). Mobile audiometry for hearing threshold assessment: A systematic review and meta-analysis. *Clinical Otolaryngology*, *49*(1), 74–86. https://doi.org/10.1111/coa.14107

Paster, M. (2011). The verbal morphology and phonology of Asante Twi. *Studies in African Linguistics*, *39*(1).

Pienkowski, M. (2017). On the etiology of listening difficulties in noise despite clinically normal audiograms. *Ear and Hearing*, *38*(2), 135–148. https://doi.org/10.1097/AUD.0000000000000388

Potgieter, J. M., Swanepoel, D. W., Myburgh, H. C., Hopper, T. C., & Smits, C. (2016). Development and validation of a smartphone-based digits-in-noise hearing test in South African English. *International Journal of Audiology*, *55*(7), 405–411. https://doi.org/10.3109/14992027.2016.1172269

Potgieter, J. M., Swanepoel, D. W., Myburgh, H. C., & Smits, C. (2018). The South African English smartphone digits-in-noise hearing test: Effect of age, hearing loss, and speaking competence. *Ear and Hearing*, *39*(4), 656–663. https://doi.org/10.1097/AUD.0000000000000522

Ramkissoon, I., & Cole, M. (2011). Self-reported hearing difficulty versus audiometric screening in younger and older smokers and nonsmokers. *Journal of Clinical Medicine Research*, *3*(4), 183–190. https://doi.org/10.4021/jocmr611w

Sarant, J., Harris, D., Busby, P., Maruff, P., Schembri, A., Lemke, U., & Launer, S. (2020). The effect of hearing aid use on cognition in older adults: Can we delay decline or even improve cognitive function? *Journal of Clinical Medicine*, *9*, 2–23.

Saunders, G. H., Frederick, M. T., Silverman, S. P. C., Penman, T., Gardner, A., Chisolm, T. H., Escabi, C. D., Oree, P. H., Westermann, L. C., Sanchez, V. A., & Arnold, M. L. (2019). Hearing screening in the community. *Journal of the American Academy of Audiology*, *30*(2), 145–152. https://doi.org/10.3766/jaaa.17103

Smits, C. (2017). Improving the efficiency of speech-in-noise hearing screening tests. *Ear and Hearing*, *38*(6), e385–e388. https://doi.org/10.1097/AUD.0000000000000446

Smits, C., & Houtgast, T. (2006). Measurements and calculations on the simple up-down adaptive procedure for speech-in-noise tests. *The Journal of the Acoustical Society of America*, *120*(3), 1608–1621. https://doi.org/10.1121/1.2221405

Smits, C., Kapteyn, T. S., & Houtgast, T. (2004). Development and validation of an automatic speech-in-noise screening test by telephone. *International Journal of Audiology*, *43*(1), 15–28. https://doi.org/10.1080/14992020400050004

Smits, C., Theo Goverts, S., & Festen, J. M. (2013). The digits-in-noise test: Assessing auditory speech recognition abilities in noise. *The Journal of the Acoustical Society of America*, *133*(3), 1693–1706. https://doi.org/10.1121/1.4789933

Stevens, G., Flaxman, S., Brunskill, E., Mascarenhas, M., Mathers, C. D., & Finucane, M. (2013). Global and regional hearing impairment prevalence: An analysis of 42 studies in 29 countries. *European Journal of Public Health*, *23*(1), 146–152. https://doi.org/10.1093/eurpub/ckr176

Summers, V., Makashay, M. J., Theodoroff, S. M., & Leek, M. R. (2013). Suprathreshold auditory processing and speech perception in noise: Hearing-impaired and normal-hearing listeners. *Journal of the American Academy of Audiology*, *24*(4), 274–292. https://doi.org/10.3766/jaaa.24.4.4

Swanepoel, D. W., Clark, J. L., Koekemoer, D., Hall, J. W., Krumm, M., Ferrari, D. V., McPherson, B., Olusanya, B. O., Mars, M., Russo, I., & Barajas, J. J. (2010). Telehealth in audiology: The need and potential to reach underserved communities. *International Journal of Audiology*, *49*(3), 195–202. https://doi.org/10.3109/14992020903470783

Swanepoel, D. W., Myburgh, H. C., Howe, D. M., Mahomed, F., & Eikelboom, R. H. (2014). Smartphone hearing screening with integrated quality control and data management. *International Journal of Audiology*, *53*(12), 841–849. https://doi.org/10.3109/14992027.2014.920965

Thammaiah, S., Manchaiah, V., Easwar, V., & Krishna, R. (2016). Translation and adaptation of five English language self-report health measures to South Indian Kannada language. *Audiology Research*, *6*(1), 1–3. https://doi.org/10.4081/audiores.2016.153

Tremblay, K. L., Pinto, A., Fischer, M. E., Klein, B. E. K., Klein, R., Levy, S., Tweed, T. S., & Cruickshanks, K. J. (2015). Self-reported hearing difficulties among adults with normal audiograms: The Beaver dam offspring study. *Ear and Hearing*, *36*(6), e290–e299. https://doi.org/10.1097/AUD.0000000000000195

Van den Borre, E., Denys, S., van Wieringen, A., & Wouters, J. (2021). The digit triplet test: A scoping review. In *International Journal of Audiology* (Vol. 60, Issue 12, pp. 946–963). Taylor and Francis Ltd. https://doi.org/10.1080/14992027.2021.1902579

Ventry, I. M., & Weinstein, B. E. (1982). The hearing handicap inventory for the elderly: A new tool. *Ear and Hearing*, *3*(3), 128–134. https://doi.org/10.1097/00003446-198205000-00006

Vermiglio, A. J., Soli, S. D., Freed, D. J., & Fisher, L. M. (2012). The relationship between high-frequency pure-tone hearing loss, hearingin noise test (HINT) thresholds, and the articulation index. *Journal of the American Academy of Audiology*, *23*(10), 779–788. https://doi.org/10.3766/jaaa.23.10.4

Vlaming, M. S. M. G., Mackinnon, R. C., Jansen, M., & Moore, D. R. (2014). Automated screening for high-frequency hearing loss. *Ear and Hearing*, *35*(6), 667–679. https://doi.org/10.1097/AUD.0000000000000073

Wilson, R. H., Burks, C. A., & Weakley, D. G. (2005). A comparison of word-recognition abilities assessed with digit pairs and digit triplets in multitalker babble. *Journal of Rehabilitation Research & Development*, *42*(2), 499–510.

World Health Organization. (2001). *International classification of functioning, disability and health: ICF*.

World Health Organization. (2021a). *Hearing screening considerations for implantation*. https://doi.org/CC BY-NC-SA3.0 IGO

World Health Organization. (2021b). *World report on hearing*. World Health Organization.

Zadeh, L. M., Silbert, N. H., Sternasty, K., Swanepoel, D. W., Hunter, L. L., & Moore, D. R. (2019). Extended high-frequency hearing enhances speech perception in noise. *Proceedings* *of the National Academy of Sciences of the United States of America*, *116*(47), 23753–23759. https://doi.org/10.1073/pnas.1903315116

Zokoll, M. A., Hochmuth, S., Warzybok, A., Wagener, K. C., Buschermöhle, M., & Kollmeier, B. (2013). Speech-in-noise tests for multilingual hearing screening and diagnostics. *American Journal of Audiology*. https://doi.org/10.1044/1059-0889(2013/12-0061)

CHAPTER 2

Development of Audiology in Ghana: Past, Present, and Future

Sesi Collins Akotey[1], Jemima Anowa Fynn[2], George Kweku Danful[1], Yaw Nyadu Offei[3], Geoffrey, K. Amedofu[2]

[1]University of Ottawa, School of Rehabilitation Sciences, Faculty of Health Sciences, Canada. Email:

[2]Korle-Bu Teaching Hospital, Hearing Assessment Center, Korle Bu, Accra.

[3]University of Education, Winneba, Department of Special Education, Winneba.

Published by the International Journal of Audiology, TIJA-2023-09-0304.R1; DOI - 10.1080/14992027.2023.2263813

To cite this article: Sesi Collins Akotey, Jemima Anowa Fynn, George Kweku Danful, Yaw Nyadu Offei & Geoffrey K. Amedofu (2023). Development of audiology in Ghana: past, present, and future. International Journal of Audiology, DOI: 10.1080/14992027.2023.2263813

Authors Contributions

Sesi Collins Akotey: Conceived the idea for the paper, developed the framework, assembled the team, articulated the purpose, collected data, conducted data analysis, and wrote the manuscript.

Jemima Anowa Fynn and George Kweku Danful: Contributed ideas, provided relevant records, participated in data analysis, and co-wrote sections of the manuscript.

Yaw Nyadu Offei: Provided oversight and editorial input, reviewing the manuscript for clarity and coherence.

Geoffrey K. Amedofu: Supplied historical documents and insights, forming the historical foundation of the paper.

Abstract

Objectives: This paper provides an overview of Ghana's audiology journey, tracking its evolution since the 1970s. It explores the historical context, transitions, and the current state of audiology in Ghana, highlighting the challenges and prospects.

Design: Descriptive and analytic approach drawing from diverse qualitative and quantitative data sources.

Study sample: The study encompasses various sources and data types, such as reports, academic literature, and statistical data. It also incorporates information related to developing audiology programmes in tertiary institutions, mobile van outreach units, cochlear implant surgeries and newborn hearing screening.

Results: Ghana's audiology journey has transformed significantly since its inception in the 1970s. From its humble beginnings with few audiologists and limited facilities, audiology has transitioned from an unknown field to growing recognition. The emergence of audiology programmes in tertiary institutions signals progress. Challenges persist such as disparity in facility distribution, low professional employability, and limited access. Nevertheless, initiatives like cochlear implant surgeries, and newborn hearing screening programmes reflect proactive steps.

Conclusion: Ghana's audiology journey is a testament to visionary thinking, dedication, and collaborative efforts. While the journey has been marked by significant developments, bridging disparities, ensuring equitable facility distribution, and formulating comprehensive policies are pivotal.

Key words: Ghana, Audiology, Newborn screening, Cochlear implant

The Context

Ghana, a West African country with a population of 30,792,608 (Ghana Statistical Service (GSS), 2021, shares borders with Togo (to the East), Côte d'Ivoire (to the West) and Burkina Faso (to the North), with the Atlantic Ocean to the South. Administratively, Ghana has sixteen regions (GSS, 2021), with a rich cultural diversity by numerous ethnic groups and over seventy-nine spoken languages (Appiah & Ardila, 2020).

Development of Audiology

Audiology in Ghana emerged during the 1970s when Dr. Andreas Markides, established the first facility at Mampong Akuapem’s Deaf Education Specialist Training College (University of Education, Winneba, 2015). In the subsequent years, notably in the late 1980s, Professor George Wireko Brobby led the establishment of the Hearing Assessment Center at the Komfo Anokye Teaching Hospital (KATH) in Kumasi with support from the Commonwealth Society for the Deaf, and the Piddan Moller Foundation.

These pioneering initiatives led to subsequent audiology facilities, like the Center for Hearing and Speech Services (CHSS), in 1993, the Hearing Assessment Centers in Tamale and Korle Bu in 2000, and 2005 respectively (Audiology clinic in Ghana, n.d.). These facilities significantly bolstered audiology growth.

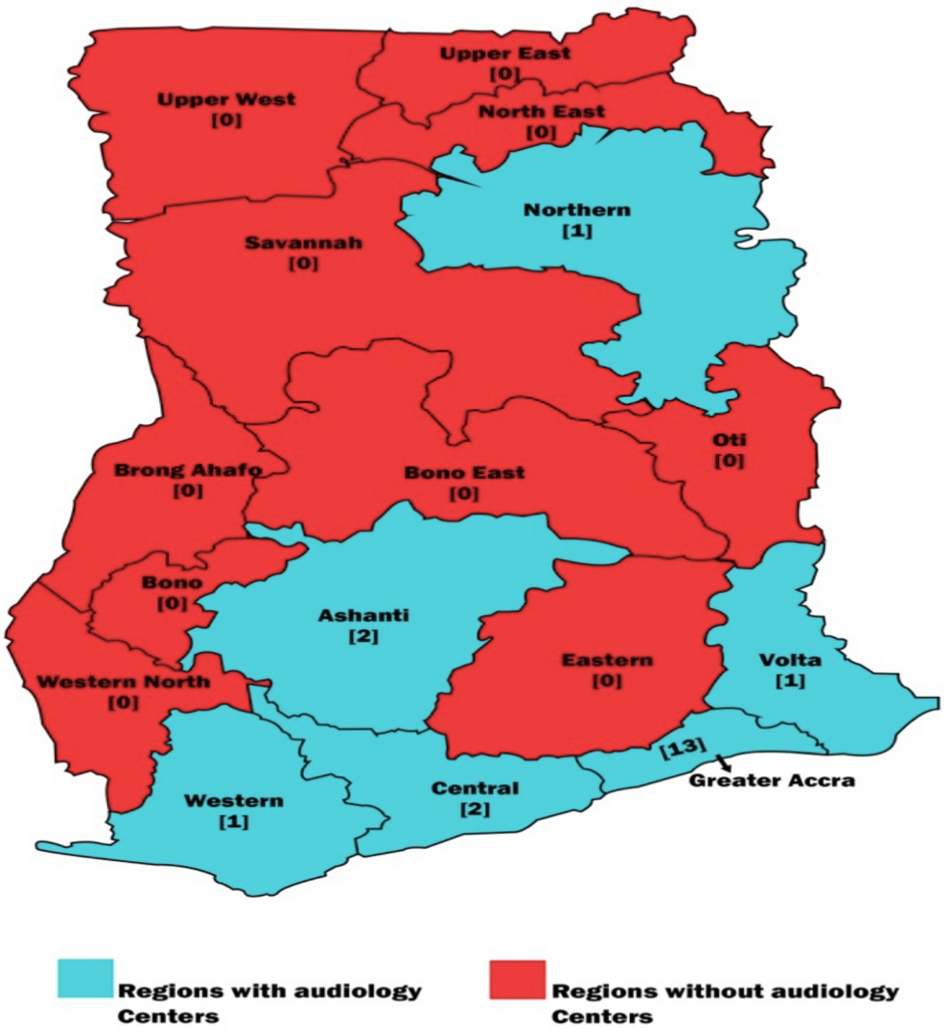
By 2015, Ghana had ten audiology facilities: four in schools for the deaf, three in hospitals, and three privately owned (University of Education, Winneba, 2015). However, an imbalance persists in distribution, with 95% concentrated in Southern regions (Figure 1). The audiologist-to-population ratio averages one per 879,789 people (Table 1). Bridging these gaps for equitable access remains a priority.

Human Resource Development

The growth of audiology in Ghana remains slow, despite the prevalence of hearing and balance disorders (Aidoo, 2018). Until 2011 Ghana had few audiologists, and they primarily trained abroad. However, overseas training's high cost posed a significant barrier, with only six audiologists serving a population of over 22 million in 2019 (Fagan & Jacobs, 2009). This deficit in professionals aligns with the findings of Mulwafu et al. (2017) underscoring the severe shortage of hearing professionals in Africa, and Swanepoel (2006), who drew attention to the insufficient number of qualified audiologists to meet the service demands in South Africa.

Recognizing the need for local expertise, in 2009, a collaboration between the Department of Special Education, University of Education, Winneba, and the Kentalis Academy in the Netherlands, yielded an online postgraduate diploma in educational audiology (University of Education, Winneba, 2015). However, this programme was not sustained. In 2011, the University of Ghana in partnership with the Church of Jesus Christ of Latter-Day Saints (LDS) introduced a Master of Science in Audiology programme. The initial faculty and equipment support came from LDS (University of Education, Winneba, 2015; Warner & Warner, 2012). Presently, additional institutions are offering audiology programmes (Table 2) resulting in a noteworthy increase in the number of audiologists from 6 to 25 by 2019 (Danful & Hammond, 2020).

Figure 1: *Distribution of audiology centers.*



Currently, there are no doctoral programmes in audiology offered in Ghana. The Allied Health Professions Council (AHPC) accredits audiology programmes, while the Speech Therapists and Audiologist Association of Ghana (STAAG) serves as the professional body. The professional journey involves passing an AHPC licensure exam.

In terms of employment, around 20% of audiologists work in public hospitals, approximately, 40% in private practice, 20% in universities, and the remaining 20% facing unemployment.

Table 1. Regional distribution of employed audiologists.

SN	Regions	Regional population	Hearing Assessment Facility		Employed audiologists	Ratio (Audiologist per Population)
			Public	Private		
1	Greater Accra	5,446,237	5	8	21	1: 259,345
2	Ashanti	5,432,485	1	1	5	1: 1,086,497
3	Eastern	2,917,039	0	0	0	0: 2,917,039
4	Central	2,859,821	2	0	5	1: 571,964
5	Western	2,057,225	1	0	0	1: 2,057,225
6	Bono	1,208,965	0	0	0	0: 1,208,965
7	Volta	1,649,523	1	0	3	1: 549,841
8	Ahafo	564,536	0	0	0	0: 564,536
9	Western North	880,855	0	0	0	0: 880,855
10	Bono East	1,203,306	0	0	0	0: 1,203,306
11	Oti	747,227	0	0	0	0: 747,227
12	Upper East	1,301,221	0	0	0	0: 1,301,221
13	Upper West	904,695	0	0	0	0: 904,695
14	Northern	2,310,943	1	0	1	1: 2,310,943
15	North East	658,903	0	0	0	0: 658,903
16	Savannah	649,627	0	0	0	0: 649,627
Total (National)		30,792,608	11	9	35	1: 879,789

Source: Census data (GSS, 2021) and field data on employed audiologists, 2022.

Access to Audiological Services

In Ghana, only 10% of the population can access audiological services (Offei, 2017). Limited awareness and the scarcity of audiologists compound this challenge (University of Education, Winneba, 2015). This shortage of professional results in low prioritization of hearing healthcare resources impacting the prevention and management of hearing loss and balance disorders (Aidoo, 2018). Despite Ghana’s involvement in infant hearing screening, the scarcity of hearing healthcare experts, notably audiologists, severely impacts service availability, leading to many infants missing essential newborn hearing screening (Ameyaw et al., 2019).

In response to these barriers, CHSS and KATH introduced mobile vans, named “HARK” (Hearing Assessment and Research ‘Klinic’) for outreach services. In 2015, the Ghanaian government, the Ghana Health Service (GHS), and the Ministry of Health (MoH) co-developed the National Medical-Outreach Service under the banner “ONUADO,” which translates to “love your neighbour” in the Akan language. The initiative deployed eight well-equipped medical vans, providing services in general medicine, ENT/Audiology, eye care, and dental care. Regrettably, with a change in government in 2017, the programme encountered a halt leaving the once-promising vans and their equipment exposed to the vagaries of the weather and circumstances (Lartey, 2020).

Table 2. Institutions offering training in Audiology.

Institution	Degree	Graduates annually
The University of Ghana, School of Biomedical and Allied Health Sciences	MSc Audiology	An average of 6 audiologists
Kwame Nkrumah University of Science and Technology, School of Medicine and Dentistry	MSc in Audiology	An average of 5 audiologists
University of Health and Allied Sciences, School of Health, and Allied Sciences	BSc Audiology	An average of 20 audiologists

Source: Field data, 2022.

Early Identification and Intervention

In July 2023, KBTH launched a two-year pilot Newborn Hearing Screening (NBHS) collaboration, involving the Ridge Hospital, the 37 Military Hospital, and Komfo Anokye Teaching Hospital (Dzakpata, 2023; Korle Bu Teaching Hospital, 2023). This ground-breaking project supported by cochlear implant manufacturer, MED-EL, and Allied Partners (Hearing Health Alliance), is anticipated to set the standard for newborn hearing screening in Ghana.

In 2021, Ghana's inaugural in-country Cochlear implant surgery began, led by KBTH and MED-EL (Koomson, 2021). Three young patients, aged two, four, and five years underwent the surgeries (Koomson, 2021). While commendable, affordability of implants remains a significant concern.

Challenges

Despite the considerable progress in Audiology in Ghana, challenges persist. Such as a national hearing healthcare policy is critical. Such a policy would provide structure, and regulation, ensuring an equitable, and efficient hearing healthcare system.

Uneven distribution of, and inadequately equipped facilities pose another challenge. Offei (2017) underscored the deficiency of cutting-edge equipment, significantly impacting the quality of audiological services in Ghana.

Financial constraints add to the complexity by limiting accessibility for many clients. Despite Ghana's evolving National Health Insurance Scheme (NHIS), audiological services remain not covered, posing a marked disparity.

Prospects

Advancements in technology, achieved through public-private partnerships, are essential in addressing the rising demand for audiologists due to age-related hearing loss (Danful & Hammond, 2020). The Government and all stakeholders must unite to establish new audiological facilities, well-equipped, ensuring nationwide access, while simultaneously formulating comprehensive guidelines or policies for standards within the audiology sector to foster professionalism and enhance service quality.

Building and expanding the KBTH NBHS nationwide is necessary to lower the age of hearing loss identification and facilitate early intervention. Exploring telehealth options, as suggested by Ameyaw et al. (2019), can improve access, and reduce travel costs.

Local research initiatives shed light on Ghana-specific hearing health issues, including chronic otitis media, earwax impaction, hearing loss especially among school children, the role of genetics and industrial hearing loss (Adadey et al., 2017, 2020; Akotey et al., 2017; Amedofu et al., 2006; 2006; Appiah-Thompson et al., 2020; Osei et al., 2018). Research informs culturally appropriate interventions and contributes to the global knowledge base.

By implementing these strategies, Ghana can improve its hearing healthcare system, ensuring accessibility, quality, and responsiveness to the needs of its people.

Conclusion

Ghana’s audiology practice demonstrates visionary thinking, determination, and collaboration. Bridging disparities, ensuring equitable facility distribution, and formulating comprehensive policies are pivotal. These efforts position Ghana’s audiology practice for continued growth, and improved hearing healthcare for its citizens.

Acknowledgement

The authors wish to acknowledge the role of the following individuals and organizations in advancing audiological services in Ghana: Dr. Neal Boafo, Dr. Christian Kwetey Kweitsu, Joseph Essel, Moses Atimo Amihere, Daniel Avoryem Tumpi, Grace Ocansey, Barbara Antwi, Kofi Asante, the Rotary Club Llanelli - Scotland, the Rotary Club of Accra Labone - Ghana, Lions Club – Cape Coast, Lillian Foundation, Sound Seekers, Medel, Starkey Hearing Foundation, and several philanthropists. The authors are also thankful to Professor Josée Lagacé for her time and guidance.

Declaration of Interest

The authors declared no potential conflicts of interest concerning this article's compilation, authorship, and/or publication. The authors are responsible for the content and writing of the article.

Reference

Adadey, S. M., G. Awandare, G. K. Amedofu, and A. Wonkam. 2017. "Public health burden of hearing impairment and the promise of genomics and environmental research: A case study in Ghana, Africa." *Omics : A Journal of Integrative Biology* 21 (11):638–646. https://doi.org/10.1089/omi. 2017.0145

Adadey, S. M., N. Manyisa, K. Mnika, C. de Kock, V. Nembaware, O. Quaye, G. K. Amedofu, G. A. Awandare, and A. Wonkam. 2019. "GJB2 and GJB6 mutations in non-syndromic childhood hearing impairment in Ghana." *Frontiers in Genetics* 10:841. https://doi.org/10.3389/fgene.2019.00841

Adadey, S. M., O. Quaye, G. K. Amedofu, G. A. Awandare, and A. Wonkam. 2020. "Screening for GJB2-R143W-associated hearing impairment: Implications for health policy and practice in Ghana." *Public Health Genomics* 23 (5-6):184–189. https://doi.org/10.1159/000512121

Aidoo, G. 2018. Taking audiology practice in Ghana to the next level. https:// advancingaudcounseling.com/taking-audiology-practice-in-ghana-to-the next-level/

Akotey, S. C., E. K. Adza, J. B. Cobbinah, K. Darko, E. W. Ador, L. P. Arckertson, P. Dadzie-Bonney, C. Adzoe, B. Asamoah, A. A. Agomboka. 2017. Significance of ear wax impaction in school children: A case of Winneba West Circuit, Ghana. *Journal of Health, Medicine and Nursing* 35:86–91.

Amedofu, G. K., G. Ocansey, and B. B. Antwi. 2008. Characteristics of hearing-impairment among patients in Ghana. *African Journal of Health Sciences* 13 (1):110–116. https://doi.org/10.4314/ajhs.v13i1.30824

Ameyaw, G. A., J. Ribera, and S. Anim-Sampong. 2019. Interregional newborn hearing screening via telehealth in Ghana. *Journal of the American Academy of Audiology* 30 (3):178–186. https://doi.org/10.3766/ jaaa.17059

Appiah, S. O., and A. Ardila. 2020. The question of school language in multilingual societies: The example of Ghana. *RUDN Journal of Psychology and Pedagogics* 17 (2):263–272. https://doi.org/10.22363/2313- 1683-2020-17-2-263-272

Audiology Clinic in Ghana (n.d.). https://www.bsmarkham.com/mission/ Africa/May%2005/clinic.html

Danful, G. K., and P. D. Hammond. 2020. Career decision survey on audiologists and speech-language therapists in Ghana, West Africa. *International Journal of All Research Writings* 1(April), 86–91. http://ijarw. com/Users/ManuScript/ManuScriptDetails/183534bf-dab8-44c4-8c33- 56aa05bb68ab

Dzakpata, F. 2023. Korle Bu launches "game changer" hearing test for babies. https://asaaseradio.com/korle-bu-launches-game-changer-hearing- test-for-babies/

Fagan, J. J., and M. Jacobs. 2009. Survey of ENT services in Africa: Need for a comprehensive intervention. *Global Health Action* 2 (1):1932. https://doi.org/10.3402/gha.v2i0.1932

Ghana Statistical Service (GSS). 2021. Ghana 2021 population and housing census - General report volume 3D: Literacy and Education (Vol. 3D). https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3D_Literacy and Education.pdf

Hamelmann, C., G. K. Amedofu, K. Albrecht, B. Muntau, A. Gelhaus, G. W. Brobby, and R. D. Horstmann. 2001. "Pattern of Connexin 26 (GJB2) mutations causing sensorineural hearing impairment in Ghana." *Human Mutation* 18 (1):84–85. https://doi.org/10.1002/humu.1156

Koomson, J. B. 2021. Korle Bu undertakes first cochlear implant in Ghana – 3 patients receives treatment. https://www.graphic.com.gh/news/gen- eral-news/korle-bu-undertakes-first-cochlear-implant-in-ghana-3-patients- receive-treatment.html

Korle Bu Teaching Hospital 2023. Newborn hearing screening launched in Korle Bu teaching hospital. https://kbth.gov.gh/newborn-hearing-screen- ing-launched-in-korle-bu-teaching-hospital/

Lartey, N. L. 2020. Onuador medical vans for decorations, release them - Minority to gov't. https://citinewsroom.com/2020/01/onuador

Mulwafu, W., R. Ensink, H. Kuper, and J. Fagan. 2017. Survey of ENT services in Sub-Saharan Africa: Little progress between 2009 and 2015. *Global Health Action* 10 (1):1289736. https://doi.org/10.1080/16549716. 2017.1289736

Offei, Y. N. 2017. Audiology in Ghana. *International Society of Audiology - Global Audiology*. https://en.wikiversity.org/wiki/Global_Audiology/Africa/ Ghana

Osei, A. O., P. A. Larnyo, A. Azaglo, T. M. Sedzro, and E. L. Torgbenu. 2018. "Screening for hearing loss among school going children. *International Journal of Pediatric Otorhinolaryngology* 111:7–12. https:// doi.org/10.1016/j.ijporl.2018.05.018

Swanepoel, D. W. 2006. Audiology in South Africa. *International Journal of Audiology* 45 (5):262–266. https://doi.org/10.1080/14992020500485650

University of Education, Winneba 2015. UEW - Reminiscences of 2015. Warner, S. L., and C. T. Warner. 2012. Pioneering in audiology: Church aids in education via video conference. https://www.thechurchnews.com/2012/ 6/30/23225435/pioneering-in-audiology-church-aids-in-education-via- video-conference

CHAPTER 3

Translation and cross-cultural adaptation of the Revised Hearing Handicap Inventory Screening Tool into Asante-Twi

Sesi Collins Akotey[1], Josée Lagacé[1], Katrine Sauvé-Schenk[1], Christian Giguère[1]

[1]School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, Ottawa, Canada.

Published by HSOA Otolaryngology Head and Neck Surg 2023, 9: 087 DOI: 10.24966/OHNS-010X/100087

Citation: Akotey SC, Lagacé J, Sauvé-Schenk K, Giguère C (2024) Translation and Cross-Cultural Adaptation of the Revised Hearing Handicap Inventory Screening Tool into Asante-Twi. J Otolaryng Head Neck Surg 10: 087.

Authors contribution:

Sesi Collins Akotey: Conceived the idea for the paper, developed its framework, sought and obtained the necessary ethical clearances, conducted data collection and analysis, and was the primary author responsible for drafting and revising the manuscript.

Josee Lagacé, Karine Sauvé-Schenk, and Christian Giguère: Provided editorial input and expert guidance throughout the development of the paper. As members of the corresponding author's thesis advisory committee, they offered supervision, ensured the study adhered to academic and research standards, and contributed to refining the manuscript for publication.

Abstract

Objective: In line with the WHO recommendations for promoting global action for equitable access to ear and hearing care, this study aimed to translate and adapt the Revised Hearing Handicap Inventory Screening Tool (RHHI-S) into the Asante-Twi language.

Methods*:* Translation and cross-cultural adaptation guidelines were followed to translate the RHHI-S from English into Asante-Twi. The steps included preparation, forward translation, synthesis/merge translation, back translation, expert committee review, field testing, and final translation. The final version of the Asante-Twi translation was ad- ministered to adults with varying hearing loss. **Results:** The Asante-Twi version of the RHHI-S was judged to be culturally and linguistically appropriate with satisfactory semantic equivalence to the source version. The internal consistency of the instrument was high with a Cronbach’s alpha of 0.936, and a test-retest reliability of 0.946. The high internal consistency and ICC of the adapted Asante-Twi version of the RHHI-S corroborated the culture and linguistic appropriateness of the instrument for hearing loss screening. **Conclusion:** The translated and adapted Asante-Twi version of the RHHI-S by the current study was culturally and linguistically appropriate. However, field validation to evaluate the complete psychometric properties of the Twi version is needed for the clinical use and hearing screening outcome measures for self-perceived hearing handicap in adults in Ghana.

Keywords: Asante-Twi; Cross-cultural adaptation; Hearing loss; Self-reported hearing measure; Translation

Introduction

Hearing is a critical sense and a key component of intrinsic human capacity. Any reduction in hearing can lead to severe consequences on interpersonal communication, quality of life, functional ability, economic independence, and general well-being [1,2]. Globally, 1.5 billion people experience hearing loss, of which 430 million would require hearing care [2]. The economic impact of unexamined hearing loss is approximately 950 billion international dollars annually [2]. Early identification via screening and appropriate management are vital in curbing the consequences of hearing loss. Hearing screening for at-risk individuals thus facilitates early identification, stimulates early management and intervention processes to reduce the impact of unidentified and untreated hearing loss. Hearing screening for early identification is therefore considered cost-effective [1], to mitigate the global burden of unexamined hearing loss.

Meanwhile, in sub-Saharan Africa, access to hearing care services appears to be extremely poor and inequitably distributed, compared to more affluent parts of the world [3]. Consequently, hearing screening at regular intervals for age-appropriate populations remains suboptimal or virtually unavailable in sub-Saharan Africa despite the proven benefits [4]. The prevalence of hearing loss and the societal cost associated with unaddressed hearing loss in adults living in sub-Saharan Africa, specifically in Ghana, highlights the need to develop effective hearing healthcare services.

Different hearing screening techniques have been proposed to improve hearing health care over the last 50 years. For example, hearing screenings using smartphones promise to bring hearing health care to underserved communities [5]. Self-reported measures of hearing difficulties or hearing handicap have also been proven as a valuable instrument to screen for hearing loss [6]. Self-reported measures are relatively low-cost and time efficient in their administration.

Furthermore, self-reported hearing disability is positively linked with help-seeking among adults [7].

Self-reported measures are relatively new in hearing screening, and there are relatively few validated instruments. The Revised Hearing Handicap Inventory and Screening tool (RHHI-S; Cassarly et al. [8]) is an example of a validated self-reported instrument. This ten- item screening questionnaire was created with items that are common to both the Hearing Handicap Inventory for the Elderly (HHIE; Ventry & Weinstein [9]) and the Hearing Handicap Inventory for Adults (HHIA; Newman et al. [10]). Both the HHIE and HHIA are well established questionnaires with validated psychometric properties used to evaluate the self-perceived effect of hearing loss [9-13]. Compared with the HHIE and HHIA, the RHHI-S has also been validated and can be used for hearing screening of adults of all ages [8].

Each item of the RHHI-S can be answered with “No,” “Sometimes,” or “Yes,” which corresponds to a specific score, i.e., 0 for “No,” 2 for “Sometimes,” and 4 for “Yes.” The total score can then be computed and compared to a scale of hearing handicap, ranging from 0 (“no handicap”) to 40 (“maximum handicap”) or used for identifying people at risk of hearing loss. According to the authors, a score between 0-8 suggests “no hearing handicap” or a 13% probability of hearing impairment, whereas a score between 10-24 points implies a 50% probability of hearing impairment. Finally, a score between 26-40 points indicates an 84% probability of hearing impairment [8]. A cut-off of ≥6 is recommended for screening purposes and to detect hearing loss [8].

Hearing screening questionnaires are available for adults in different languages [14,15], but none is available in any Ghanaian language. There are close to 80 languages spoken in Ghana [16]. Asante-Twi is one of the four mutually intelligible dialects spoken by the Akans. It is among the nine languages being sponsored by the government, meaning it is taught and learnt in many Ghanaian schools [17,18]. Akan represent the largest ethnic group in Ghana [16,19]. For instance, 81.7% of the Central region populace, and 78.2% and 74.2% of the populace in the Western and Ashanti regions respectively of Ghana are Akans [19].

The present study aimed to translate and adapt the RHHI-S into Asante-Twi. Since most of the available self-report hearing questionnaires were developed using a well-established framework, translation and cross-cultural adaptation of existing instruments have clear advantages over creating new ones [20,21]. Hall et al. [20] have synthesized existing recommendations for cross-cultural adaptation in promoting good practice in the Audiology community. Their guide- line and recommendations were used for this study.

Materials and Methods

The 7-step translation process, as recommended by Hall et al. [20], was followed (Figure 1) for the translation and adaptation of the original version of the RHHI-S into the Asante-Twi language. It involved cultural and language considerations to maintain the concepts and meaning from the original version while ensuring cultural equivalence and appropriateness.

A total of 87 participants were recruited for the pre-testing and field evaluation of the adapted instrument. In the pre-testing, 32 participants took part in the cognitive evaluation of the adapted Asante-Twi version for its cultural equivalence and linguistic appropriateness. While 55 participants participated in the field testing to investigate the basic psychometric properties of the instrument.

Thirty-two participants for the pre-testing were recruited via social media platforms (WhatsApp) via invitation to participate in the study. Information about the study was shared on WhatsApp group platforms for university students and clients of Center Hearing and Services, Winneba.

Interested participants contacted the researcher privately through their social media contact and were later sent the instrument. According to Hall et al. [20], a sample size of at least 20 participants should be used for the pre-testing where there are regional variations and to ensure the original instructions, items and scoring materials are clearly expressed. In the field testing, participants who attended audio logical services at the Centre for Hearing and Speech Service (CHSS), Winneba, Ghana were recruited after an explanation of the instrument has been presented to them and they consented to participate. A sample size of 50 was recommended by Hall et al. [20], to evaluate the internal consistency and test-retest reliability of the adapted Asante-Twi version of the RHHI-S. Participants of the present study were aged between 18 and 73 years; were all living in Ghana and able to read and speak English and Asante-Twi. The seven steps of the translation and cultural adaptation of RHHI-S into Asante-Twi are described in the following paragraphs and illustrated in figure 1.

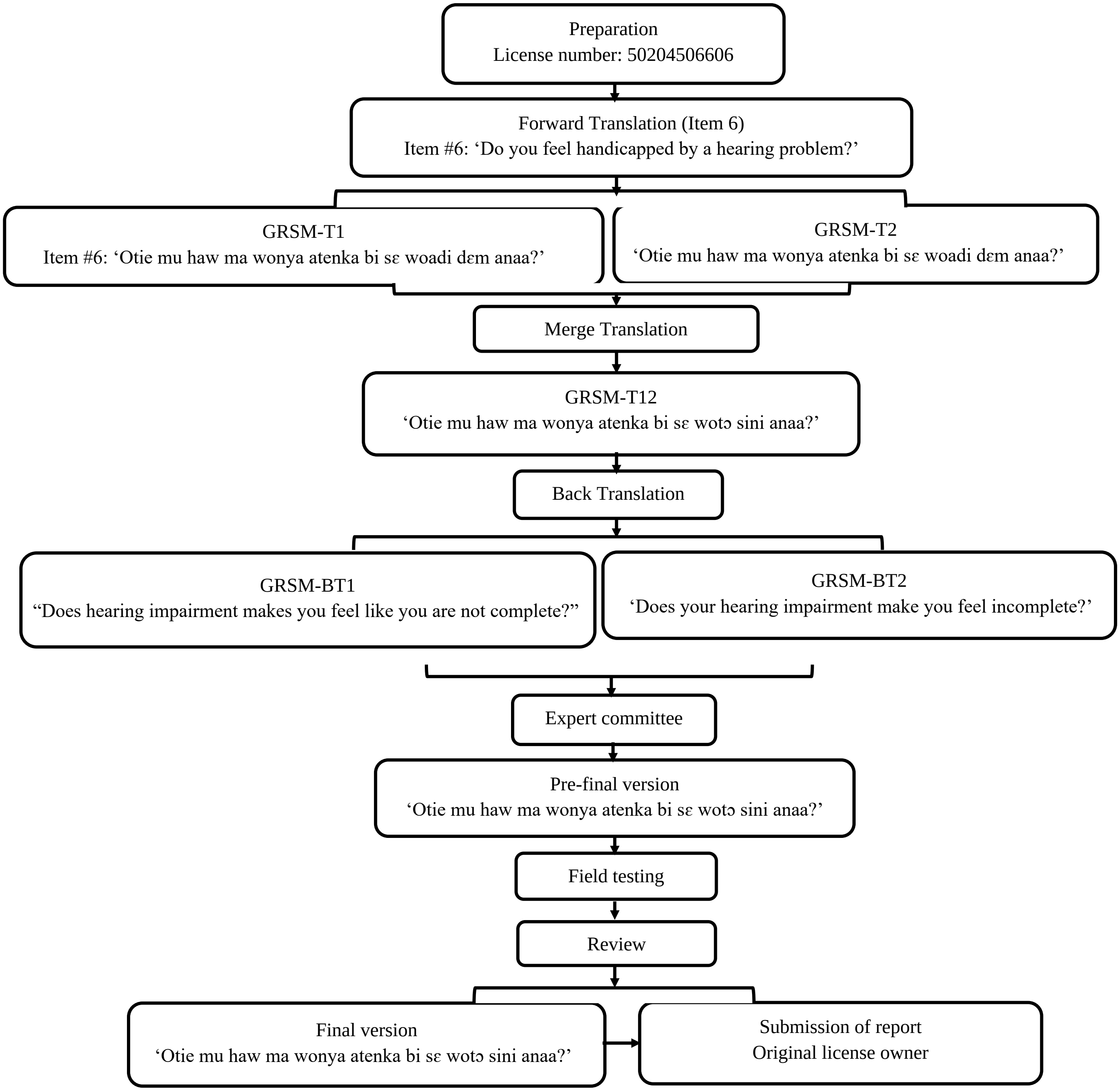
Preparation: A search in the literature was conducted to ensure the Asante-Twi version of the RHHI-S did not already exist. Findings confirmed that no versions of the RHHI-S existed in any Ghanaian language, including Asante-Twi. Following this confirmation, written permission, and a license to translate and adapt the instrument was granted by the copyright holders.

Forward Translation: Two bilingual language experts, whose moth- er tongue is Asante-Twi and who are fluent in English, independently translated the instrument from its original version to Assante-Twi. These language experts are professionals who hold at least of Bachelor of Arts degree in Twi from the School of Languages, University of Education, Winneba, Ghana. The first author briefed the language experts about the instrument and the translation process. These Asante-Twi versions of RHHI-S were code-named GSRM-T1 and GS- RM-T2.

Merge Translation: Another independent and unbiased bilingual language expert, fluent in Asante-Twi and English, merged the two forward translations (GSRM-T1 and GSRM T2) into a single document. Differences between the two initial translations were discussed and resolved by consensus among the three translators. The merged translation was called the GSRM-T12.

Back Translation: Two other independent language experts translated the merged translation (GSRM-T12) into English. The back translation was to validate the accuracy of the translation and ensure it reflected the item content as the source instrument. Without prior knowledge of the source instrument, the language experts produced two separate English translations of the merged translation, GS- RM-BT1 and GSRM-BT2.

Figure 1. Stages of the translation and cross-cultural adaptation of the RHHI-S into the Asante-Twi language. Item #6 of the questionnaire was used to illustrate the different stages of the process.



Note. Steps in cross-cultural translation and adaptation process. Adapted from "A good practice guide for translating and adapting hearing-related questionnaires for different languages and cultures," by Hall, D. A., Zaragoza Domingo, S., Hamdache, L. Z., Manchaiah, V., Thammaiah, S., Evans, C., & Wong, L. L. N. (2018). International Journal of Audiology, 57(3), 161–175.

Expert Committee Review: A panel of experts comprising two audiologists, a language expert from the School of Languages, University of Education, Winneba; an educator of persons who are deaf and hard of hearing, and the forward and back translators, discussed the backward translation and produced a pre-final version of the instrument for field testing in Ghana. The discussion was conducted by teleconference and aimed to achieve the instrument's semantic, idiomatic, experimental, and conceptual equivalence and complete the questionnaire's pre-final version. All the members of the committee were living in Ghana and fluent in both Asante-Twi and English. The first author was in contact with the committee in the waiting room throughout their meeting to provide any clarifications that may be needed concerning the concepts being measured by the questionnaire.

Field Testing: This was conducted in two stages – cognitive debriefing and pilot-testing of the instrument.

Cognitive Debriefing: In line with Hall et al. [20], guideline, a pre-testing of the Asante-Twi translation was conducted with participants who were fluent in English and Asante-Twi. Interviews were conducted with each participant. The aim was to ensure the Asante-Twi translation's instructions, the items/questions, and the scoring were straightforward. The understanding level of the items and semantic equivalence, the cultural relevance and the acceptability of the instrument were also assessed. Each participant was invited to complete the Asante-Twi translation of the instrument online, followed by a semi-structured interview. The first author conducted all the interviews, which aimed to evaluate the ease of understanding the instrument's items and identify any ambiguity. Participants were also asked to report any difficult questions to understand and to make any suggestions to improve clarity. A simple seven-response Likert scale was used to record participants' responses, using the following categories: "Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree, Agree, and strongly agree." Participants' opinions, responses and suggestions were analyzed to consolidate the correct- ness of the Asante-Twi translation and, where necessary, to incorporate changes for the final version of the adapted and the translated version (Asante-Twi).

Pilot Testing: The instrument's pre-final version was administered to participants of the target population who attended audio logical services at the CHSS. Participants completed the instrument twice with a two-week interval between the first and second completion of the instrument. The internal consistency and test-retest reliability of the adapted instrument were examined. The internal consistency examined the degree of the interrelationship among the items on the instrument and how reliably the items can measure the same con- struct. The Cronbach's alpha coefficient was used to evaluate the internal consistency of the adapted instrument to measure self-perceived handicap. An interval consistency defined by Cronbach's alpha coefficient of 0.7 is considered the minimally acceptable level for the interrelatedness of the test items. Test-retest reliability measures the reliability/consistency obtained by administrating the same test twice on the same sample at a different point in time. The Intraclass Correlation Coefficient (ICC) was used to assess the agreement between the total scores in the two administrations of the instrument-test-retest reliability.

Results

A pre-testing with 55 participants who were representatives of the target population was conducted. There were twenty-seven (27) females - representing 49.1%, and twenty-eight (28) males representing 50.9%, with a mean age of 42 years (Table 1).

Characteristic	**Mean**	**SD (%)**	**N**	**%**
Age (Years)	42	16.42		
Male Gender			28	50.9
Female Gender			27	49.1
Total			55	100

Table 1. Sample demographics for field testing (n=55)

Cognitive Debriefing: All participants (100%) strongly agreed that the items were clear and understandable. Participants further disagreed or strongly disagreed (100%) that words or phrases in the instrument's items were difficult. Again, participants unanimously (100%) disagreed with making any changes to any questions. Participants scored the clarity of the items on a scale of one (1) to seven (7) on the Likert scale, where one (1) represented strongly disagree and seven (7) strongly agree. Scores for the clarity of the items in the adapted instrument and instructions ranged from 6 to 7 out of 7. A score above 4 indicates that the items are clear and do not re- quire revision [22, 23]. As a result, there were no changes made to the pre-final version of the instrument regarding words or phrases as participants suggested clarity and understanding of the individual items. All the items and wording were culturally relevant, intelligible, and non-offensive.

Results from the pilot testing showed that the overall internal consistency of the adapted and translated version for the 10 items was 0. 936. The test-retest reliability of the instrument was assessed using the Intraclass Correlation Coefficient (ICC), yielding a substantial agreement of 0.946 with a 95% confidence interval between 0.921 and 0.965 (Table 2).

	ICC	95% Confidence Interval		F Test with True value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Average Measures	0.946[c]	0.921	0.965	18.379	54	486	0.000

Table 2. Test-retest reliability of the Asante-Twi version. **Note:** ICC absolute agreement

Discussion

The study aimed to translate and adapt the RHHI-S into Asante-Twi. Asante-Twi is considered the most widely spoken dialect in Ghana [19]. The guideline and recommendations from Hall et al. [20], were used to achieve linguistic and cultural equivalence between the source instrument (RHHI-S) and the translated and adapted version in Asante-Twi. Interviews conducted with participants from the Ghanaian population suggested that the cultural equivalence and con- tent validity of the Asante-Twi version of the RHHI-S was satisfactory. The words and sentences of this adapted version of the instrument were judged culturally appropriate, and non-offensive with satisfactory semantic equivalence to the source version.

During the pilot testing of the pre-final version of the Asante-Twi RHHI-S, participants did not show any difficulty completing the items. This could be attributed to the successful, cultural equivalence and linguistic appropriateness of the adapted and translated Asante-Twi version of the RHHI-S translation.

The internal consistency of the Asante-Twi version of the RHHI-S was evaluated by estimating Cronbach's alpha value. Results for the investigation showed a high internal consistency of the adapted instrument, thus, a Cronbach's alpha coefficient of α=0.936. This is indicative of a strong internal consistency of the test items. To a larger extent, the scores obtained from these 10 items are consistent and dependable, making the adapted and translated version a reliable instrument for assessing the intended construct. This finding is consistent with the findings of Newman et al. [24], indicating the instrument's ability to measure the construct of self-perceived handicap.

Investigating the test-retest reliability of the Asante-Twi version using the intraclass correlation coefficient showed high test-retest reliability of the test items with an ICC score of 0.946 for all the items. This finding indicates a high level of reliability in the test-retest measurements of the Asante-Twi Version, as supported by the significant F test and a narrow confidence interval around the ICC. These findings are similar to that of the source instrument [8], showing stability and high reliability in the test-retest ability of the instrument. Newman et al. [24] reported test-retest reliability to range from 0.93 to 0.97.

Notwithstanding these findings, further investigations of the instrument the psychometric properties (predictive validity, and construct validity), sensitivity, specificity, and the cut-off point of the Asante-Twi version of the RHHI-S need to be assessed before this hearing screening is used clinically.

Strengths and Limitations

A strength of the current study was the adherence to the guideline provided for the cross-cultural translation and adaptation. As described in Hall et al. [20], guideline, each step was followed, resulting in the cultural relevance and satisfactory semantic equivalence of the translated and adapted versions. The study also used participants from the target population [25-27].

A limitation of the present study is that the sample of participants did not necessarily represent native Asante-Twi speaking Ghanaian population with specific reference to location. Participants for the cur- rent study were recruited from one geographical location - Winneba. There is a need for a more representative sample of Asante-Twi populace. This could be considered and implemented during the validation of the adapted questionnaire.

Conclusion

The development of validated and culturally adapted hearing instrument tools is in line with WHO's recommendations of promoting actions for equitable access to ear and hearing care across the world. The present study's objective was to translate and adapt the RHHI-S into Asante-Twi, one of Ghana's most spoken languages. The translated and adapted Asante-Twi version of the RHHI-S by the current study was culturally and linguistically appropriate. However, the psychometric properties (predictive validity, construct validity, and concurrent validity) of the Asante-Twi version of the RHHI-S need to be assessed before it is used as a hearing screening tool.

Declaration of Interest

The authors declared no potential conflicts of interest concerning the translation and adaptation, authorship, and/or publication of this article. The authors are responsible for the content and writing of the article.

Acknowledgment

The authors are thankful to members of the expert committee; Nicholas Obeng Agyekum, Cyril Mawuli Honu-Mensah, George Kweku Danful, and Emmanuella Ampabeng; and the translators; Derrick Oppong, Seth Amoah, Samuel Boakye, Stephen Asante and Prince Osei Mensah, for their role in the translation process. We are grateful to Yaw Nyadu Offei (Ph.D.) and Mawuli Tay for their helpful discussions regarding the cultural relevance of the paper and the analysis of the data sets. The authors are also thankful to all participants.

Reference

1. World Health Organization (2017) Global costs of unaddressed hearing loss and cost-effectiveness of interventions. World Health Organization, Geneva, Switzerland.
2. World Health Organization (2021) World report on hearing. World Health Organization, Geneva, Switzerland.
3. Mulwafu W, Kuper H, Ensink RJH (2016) Prevalence and causes of hearing impairment in Africa. Trop Med Int Health 21: 158-165.
4. Mulwafu W, Ensink R, Kuper H, Fagan J (2017) Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015. Glob Health Action 10: 1289736.
5. Hussein SY, Swanepoel DW, de Jager, LB, Myburgh HC, Eikelboom RH, et al. (2016) Smartphone hearing screening in mHealth assisted community-based primary care. J Telemed Telecare 22: 405-412.
6. Smits C, Kramer SE, Houtgast T (2006) Speech reception thresholds in noise and self-reported hearing disability in a general adult population. Ear Hear 27: 538-549.
7. Knudsen LV, Oberg M, Nielsen C, Naylor G, Kramer SE (2010) Factors influencing help seeking, hearing aid uptake, hearing aid use and satisfaction with hearing aids: A review of the literature. Trends Amplif 14: 127-154.
8. Cassarly C, Matthews LJ, Simpson AN, Dubno JR (2020) The revised hearing handicap inventory and screening tool based on psychometric re- evaluation of the hearing handicap inventories for the elderly and adults. Ear Hear 41 95-105.
9. Ventry IM, Weinstein BE (1982) The hearing handicap inventory for the elderly: A new tool. Ear Hear 3: 128-134.

10. Newman CW, Weinstein BE, Jacobson GP, Hug GA (1990) The hearing handicap inventory for adults: Psychometric adequacy and audiometric correlates. Ear Hear 11: 430-433.

11. Chisolm TH, Johnson CE, Danhauer JL, Portz LJP, Abrams HB, et al. (2007) A systematic review of health-related quality of life and hearing aids: Final report of the American academy of audiology task force on the health-related quality of life benefits of amplification in adults. American Academy of Audiology 183: 151-183.

12. Hospers JMB, Smits N, Smits C, Stam M, Terwee CB, et al. (2016) Re-evaluation of the Amsterdam inventory for auditory disability and handicap using item response theory. Journal of Speech, Language, and Hearing Research 59: 373-383.

13. Lazzarotto S, Baumstarck K, Auquier P (2016) Age-related hearing impairment and impact on quality of life: A review of available questionnaires. Ann Otolaryngol Rhinol 3: 1107.

14. Laohasiriwong S, Kasemsiri P, Thanavirathananich P, Yimtae K (2018) Validity and Test-Retest Reliability of Hearing Handicap Inventory for the Elderly Thai Version (HHIE-Thai). Annals of Otolaryngology and Rhinology 5: 1204.

15. Thammaiah S, Manchaiah V, Easwar V, Krishna R (2016) Translation and adaptation of five English language self-report health measures to South Indian Kannada language. Audiology Research 6: 1-3.

16. Appiah SO, Ardila A (2020) The question of school language in multilingual societies: the example of Ghana. RUDN Journal of Psychology and Pedagogics 17: 263-272.

17. Agbozo GE (2015) Language choice in Ghanaian classrooms: Linguistic realities and perceptions. Norwegian University of Science and Technology.

18. Owu-Ewie C (2003) The language policy of education in Ghana: A critical look at the English-only language policy of education. Project Management Journal 33: 171-175.

19. Ghana Statistical Service (2013) 2010 Population & Housing Census National Analytical Report. Ghana Statistical Service 1-91.

20. Hall DA, Domingo SZ, Hamdache LZ, Manchaiah V, Thammaiah S, et al. (2018) A good practice guide for translating and adapting hearing-related questionnaires for different languages and cultures. Int J Audiol 57: 161- 175

21. Wild D, Eremenco S, Mear I, Martin M, Houchin C, et al. (2009) Multinational trials - Recommendations on the translations required, approaches to using the same language in different countries, and the approaches to sup- port pooling the data: The ISPOR patient-reported outcomes translation and linguistic validation good research practices task force report. Value Health 12: 430-440.

22. Tremblay D, Poder TG, Vasiliadis HM, Touati N, Fortin B, et al. (2020) Translation and cultural adaptation of the patient self-administered financial effects (P-safe) questionnaire to assess the financial burden of cancer in French-speaking patients. Healthcare 8.

23. Vallerand RJ (1989) Towards a methodology for transcultural validation of psychological questionnaires: Implications for research in the French language. Psychol Can 30: 662-689.

24. Newman CW, Weinstein BE, Jacobson GP, Hug GA (1991) Test-retest re- liability of the hearing handicap inventory for adults. Ear and Hearing 12: 355-357.

25. Bland J, Altman D (1997) Statistics notes: Cronbach’s alpha. British Medical Journal 314: 572.

26. Chou R, Dana T, Bougatsos C, Fleming C, Beil T (2011) Screening adults aged 50 years or older for hearing loss: A review of the evidence for the U.S. preventive services task force. Annals of Internal Medicine 154: 347- 355.

27. Offei YN (2017) Audiology in Ghana. Global Audiology 1- 6. https://en.wikiversity.org/wiki/Global_Audiology/Africa/ Ghana

CHAPTER 4

Development and Evaluation of Ghanaian Digit Triplet Test in Asante-Twi and Ghanaian English

*Sesi Collins Akotey, Josée Lagacé, Christian Giguère, Katrine Sauvé-Schenk,

School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, 200 Lees Avenue, Ottawa, Ontario K1N 6N5, Canada.

Submitted to the International Journal of Audiology (ID: 246305444)

Author contribution:

Sesi Collins Akotey: Conceived the idea for the paper, developed its framework, sought and obtained the necessary ethical clearances, conducted data collection and analysis, and was the primary author responsible for drafting and revising the manuscript.

Josee Lagacé, Karine Sauvé-Schenk, and Christian Giguère: Provided critical editorial input and expert guidance throughout the development of the paper. As members of the corresponding author’s thesis advisory committee, they offered supervision, ensured the study adhered to academic and research standards, and contributed to refining the manuscript for publication.

Abstract

Objectives: This study aimed to develop and evaluate a Ghanaian Digit Triplet Test for adult hearing screening.

Design: The study was conducted in two phases. Phase 1 optimized digit recognition across speech materials in a controlled environment, while Phase 2 collected normative data and assessed list equivalence using an adaptive and fixed-level method.

Study Sample: Eighty adults aged 18 to 50 with normal hearing thresholds (≤ 15 dB HL) participated: 16 in Phase 1 and 64 in Phase 2.

Results: The mean SRTs were -11.3 dB for Asante-Twi and -11.4 dB for Ghanaian English, closely matching other digit triplet tests. Psychometric slopes were 17.9%/dB for Asante-Twi and 19.4%/dB for Ghanaian English. No significant differences were found in SRTs across list numbers or orders for the Asante-Twi version, indicating list equivalence and no learning effect. However, a significant learning effect in the Ghanaian English version necessitated different normative values based on participants' test exposure.

Conclusion: The GDTT demonstrates consistency with other digit triplet tests while addressing specific linguistic and cultural factors. The test can improve access to hearing screening in resource-limited settings in Ghana. Further research should explore the test's applicability to a broader demographic, including children.

Keywords: Digit triplet test, hearing screening, hearing loss, Asante-Twi, Ghana

Introduction

Hearing loss, whether caused by aging, exposure to loud sounds, or injury, is associated with loss of productivity (Huddle et al., 2017), emotional and social loneliness (Stam et al., 2016), and an increased risk of dementia and cognitive decline (Gates et al., 1996; Lin et al., 2011; Livingston et al., 2020; Sarant et al., 2020; Uhlmann et al., 1989). Globally, an estimated 83% of hearing loss goes unaddressed; and the overall global economic cost of hearing loss in 2019 was over 981 billion American dollars (McDaid et al., 2021). In Ghana, hearing loss is a common health condition among the adult population, and in many cases, it is not being addressed. This situation is multifactorial.

Although the early identification of hearing loss is pivotal and a prerequisite for the implementation of effective intervention programs, especially in developing countries with high population density and few hearing care resources (Zhang et al., 2019), many barriers prevent the general implementation of adult screening such as high cost of audiological equipment and trained personnel (Zhang et al., 2019) and limited access to audiological services (Akotey et al., 2023; Fagan & Jacobs, 2009; Mulwafu et al., 2017). However, recent technological advancements have enabled the development of different hearing screening options that can be used in areas with limited resources to widen access to hearing screening. The negative impact of unaddressed hearing loss and the global burden of these consequences underscore the need to mobilize to increase access to adult hearing screening, specifically for countries with limited resources.

Adult hearing screening typically consists of various components that are designed to identify any abnormalities or deficits in the auditory system or related health conditions that could impact hearing functions and the ability to participate in daily life activities (ASHA, n.d.). According to World Health Organization (2021), hearing screenings in adults should be conducted in two stages.

The first part involves inquiring about the person’s self-perceived hearing status and experiences of any hearing difficulties in daily life using methods including validated questionnaires, such as the Hearing Handicap Inventory for the Elderly (HHIE; Ventry & Weinstein, 1982). The second stage of adult hearing screening involves the objective detection of hearing loss. For example, hearing can be checked by measuring responses to pure tones presented at a target screening sound level. However, this technique can be challenging in certain settings, such as those lacking proper acoustic properties, calibrated equipment, or qualified test administrators (Jansen et al., 2014; Oremule et al., 2024). Other methods, such as the Digit Triplet Test (DTT; Smits et al., 2004) have been developed to overcome these challenges. Compared to pure-tone screening, the DTT hearing screening test offers an affordable and accessible alternative for developing countries (Potgieter et al., 2016). It overcomes access barriers to first-line screening services and reduces the cost of administering a hearing screening program (Jansen et al., 2010; Smits et al., 2004). Additionally, DTT uses very familiar spoken words, digit triplets, as speech material (Potgieter et al., 2016) and does not require a lot of training. A high correlation between DTT scores and pure-tone thresholds has been previously reported (Smits et al., 2004; Watson et al., 2012).

The Digit Triplet Test was originally developed in Dutch as an over the telephone self-assessment hearing screening tool to promote consultation with a hearing specialist. It is a speech-in-noise screening test that uses combinations of three digits, also called digit triplets, as speech material. The DTT uses an adaptive procedure to determine the speech reception threshold (SRT). This threshold corresponds to the speech-to-noise ratio at which 50% of the triplets are correctly recognized. The DTT is now available and administered on a wide range of platforms including smartphones (Potgieter et al., 2016) and personal computers (Folmer et al., 2017; Giguère et al., 2020).

Due to its efficiency and popularity, the DTT has been adapted into more than 15 languages (Cameron et al., 2016; Çetinkaya & Konukseven, 2023; Dillon et al., 2016, 2016; Folmer et al., 2017; Giguère et al., 2020; Jamaluddin, 2016; Jansen et al., 2010; King, 2010; Ozimek et al., 2009; Pérez-González et al., 2013; Potgieter et al., 2016; Vlaming et al., 2014; Wagener et al., 2006; Wang & Wong, 2023; Warzybok et al., 2016; Williams-Sanchez et al., 2014). In some cases, there is more than one version of the DTT in each implementation to deal with multilingual environments and to control for intelligibility problems due to cultural differences (e.g., pronunciation, accent). This is notably the case for the European French (Jansen et al., 2010, 2013) and Canadian French and English (Giguère et al., 2020) versions of the DTT.

This study outlines the development and evaluation of the Ghanaian Digit Triplet Test (GDTT), featuring digit triplets in Asante-Twi and Ghanaian English. The same test construction procedure was used for both language versions, following the International Collegium of Rehabilitative Audiology (ICRA) guidelines (Akeroyd et al., 2015). Administratively, Ghana is divided into 16 regions; and boasts over 79 indigenous languages (Agbozo, 2015; Appiah & Ardila, 2020), and Akan is the largest ethnolinguistic group (47.5% of the population) (Agbozo, 2015). Akan has several dialects, including Asante-Twi, Akuapem-Twi, and Fante (Paster, 2011), with Asante-Twi being the most used dialect across all 16 administrative regions (Ghana Statistical Service, 2021). Despite being a multilingual nation, Ghana primarily uses English for education, which serves as a second language for over 96% of individuals aged six and above who attend school (Ghana Statistical Service, 2021). However, English in Ghana has evolved uniquely by blending local linguistic and cultural influences into its vocabulary, pronunciation, and idiomatic expressions (Adika, 2012). English-speaking Ghanaians often exhibit spelling pronunciations that are influenced by the complex relationship between English orthography and sound in their native languages (Adika, 2012). Therefore, improving access to hearing screening and early identification of hearing loss among the Ghanaian adult population calls for the implementation a language-based hearing screening tool available in Asante-Twi and Ghanaian English. This approach ensures inclusivity and effectiveness, catering to the linguistic diversity of the population and maximizing the reach of the screening efforts.

The study is part of a doctoral research project approved by the Research and Ethics Board, University of Ottawa, Canada, under file number H-05-21-5674. The test was developed in Ottawa (Canada) and evaluated in Winneba (Ghana).

Methodology

Speech Materials and Masking Noise

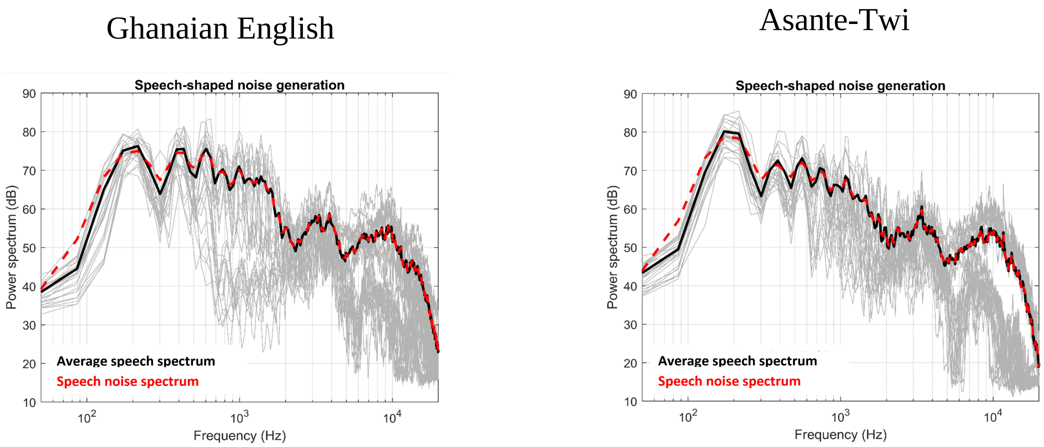
For both the Asante-Twi and Ghanaian English versions, 27 triplet tokens (digits 1- 9) were recorded in a sound-attenuating booth at the Hearing Research Laboratory (University of Ottawa, Ottawa, Canada). The order of the digits was counterbalanced, such that every digit occurred three times in each triplet position (first, second, and third positions). A native female speaker of Asante-Twi (32 years old), also fluent in Ghanaian English, participated in the recordings. She had learned Asante-Twi from birth and Ghanaian English by three years of age. A directional cardioid condenser microphone (Shure PG81) was used for the recording. The speaker was instructed to use her typical vocal effort and incorporate natural pauses between digits and digit sequences. The test tokens include digits one to nine to ensure token homogeneity between the two versions. For both the Asante-Twi and Ghanaian English versions of the DTT, the digit "zero" was omitted because it is not a polysyllabic word in Asante-Twi as the other digits.. This is similar to the Polish DTT (Ozimek et al., 2009). A short carrier phrase, “The digits” for the Ghanaian

English version, and “Aba” for the Asante-Twi version were also recorded. Triplets and carrier phrases were saved as distinct sound files (*.wav).

After the recordings, the digits to be used at each position of the triplets were selected by the first author, who was also a proficient speaker of both Asante-Twi and Ghanaian English. The most naturally spoken tokens, free of acoustic artifacts, were selected. The original digit positions within the triplets during production were maintained to preserve the prosody and intonation quality. Each list was counterbalanced to ensure that each digit occurred three times in each digit sequence position. This process produced three lists of 27 triplets for each language version, ensuring that digits were neither repeated nor presented in their natural order within a triplet. Each triplet token was resynthesized by concatenating individual-digit tokens in real-time, with a 160 ms pause both at the beginning and end of each digit during playback. These synthesized triplet tokens were incorporated into the cross-platform Java application, which allowed randomization of the triplet presentation order in each of the three lists for each language. Additionally, each triplet was introduced by its respective language-specific carrier phrase.

Language-specific noise was generated for each language version of the GDTT by utilizing the average spectra of the 27-digit tokens for each language. A filter was applied to generate a noise with equivalent long-term spectral characteristics to the digit material for both language versions. The average spectra of the digits and superimposed speech noise for both the Ghanaian English and Asante-Twi DTT versions are displayed in Figure 1. During testing, language-specific noise was introduced 500 ms before the carrier phrase and persisted for 500 ms after the end of each triplet.

Figure 1. Spectra of the 27 digits and speech noise (overlying) used in the GDTT

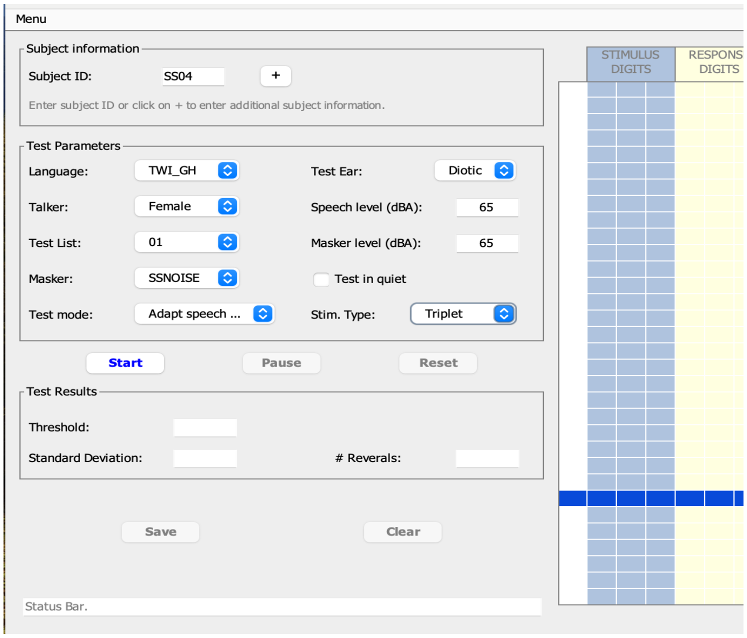


Test Interface and Calibration

The GDTT was developed using the same cross-platform Java application that was created for the Canadian version of the DTT (see Giguère et al., 2020 for more details). The platform can run on any major operating system (e.g., Windows, Mac OS, or Linux). The testing interface allows entry of participant information (e.g., identification number), selection of test parameters, test execution, and saving of results (Figure 2). The software configuration allows the tester to hide the main interface to prevent participants from seeing the stimulus digits while running the GDTT.

The interface also includes a stimulus-response digit table to update the operator on the participant’s response and progress throughout the test. The software further allows the storage of application settings, list definitions, default test parameters, calibration values, and test results in Excel files. In this study, sound playback was achieved using a USB audio interface (Olympus 2 E10K) and Radioear DD45 earphones (Radioear, Eden Prairie, MN) connected to a Dell laptop computer. The participants responded using an external USB numeric keypad (Peripad-202 HW, Perixx Computer, Dusseldorf, Germany) connected to the Dell laptop computer.

Figure 2. Testing interface of the GDTT



The GDTT recordings were calibrated using a Bruel and Kjaer Type 4152 artificial ear connected to a sound-level meter. The Radioear DD45 earphones were coupled to the artificial ear, and the noise stimuli were individually calibrated for each (left or right) earphone and both language versions, maintaining a consistent level of 65 dBA.

Participants

A total of 80 adults aged 18 to 50 years (Table 1), fluent in both Asante-Twi and Ghanaian English, and with normal hearing thresholds (≤ 15 dB HL) at octave frequencies from .25 to 8 kHz, participated in the study (Phases 1 and 2). All participants had learned the language from birth and Ghanaian English by age six, when they started Basic School. For each phase of the study, all participants were invited to complete a consent form and questionnaire on general hearing health, language development, and proficiency.

Sixteen adults were recruited from the Ghanaian community in Ottawa (Canada) to participate in Phase 1 of the study. Testing was conducted at the Hearing Research Laboratory at the University of Ottawa (Ottawa, Canada).

Testing for Phase 2 was conducted in a double-walled audiometric booth at the Center for Hearing and Speech Services (Winneba, Ghana). A total of 64 adults were recruited for Phase 2, comprising 16 native speakers of Asante-Twi, 16 non-native speakers of Asante-Twi (i.e., having learned Asante-Twi after age 6), and 32 participants who were fluent in Ghanaian English (Table 1). Testing in this phase included measures with an adaptive and a fixed level procedure.

Table 1. Participant characteristics.

Study Phases	**N**	**Gender (male/female)**	**Age (Years)**	
			Mean	**(Min-Max)**
Phase 1: Asante-Twi and Ghanaian English	16	11/5	34.9	27-50
Phase 2: Asante-Twi (Native speakers)	16	7/9	26.3	21-35
Phase 2: Asante-Twi (Non-native speakers)	16	5/11	25.0	21-31
Phase 2: Ghanaian English	32	13/19	25.1	20-32

Procedures and Results

The following paragraphs present the procedures involved in Phase 1, which aimed at digit optimization, and Phase 2, which was conducted to establish equivalence between triplet lists and normative statistical values. In each phase, participants were presented with a trial test with at least 10 triplets. The aim was to familiarize participants with the testing protocol and response procedure for a smooth transition into the subsequent testing.

Phase 1 – Optimization of the Digits

The testing conducted in Phase 1 aimed to homogenize the recognition of individual digits across speech materials. The testing was conducted in a double-walled audiometric booth, and the test stimuli were presented binaurally. The order of the three lists of digit triplets was counterbalanced across participants and test conditions for both language versions of the test. All triplets were accompanied by the language-specific speech-shaped noise at 65 dBA and were preceded by language-specific carrier phrases. Recordings in both versions were presented at six signal-to-noise ratios (SNR): -20, -17, -14, -11, -8, and -5 dB.

Participants were instructed to input their responses through an external numeric keypad connected to the test computer, with the provision to guess when uncertain. Participants were not informed of the absence of the digit 'zero' in either language version. Scoring was done at the digit level, considering all digits (0 to 9) as potential options. The mean digit recognition score was calculated for each digit by position at each SNR for both versions of the GDTT. A logistic model psychometric function (Zokoll et al., 2012) was fitted to the mean data at each SNR for the nine-digit stimuli at the three positions. The model incorporates a 10% chance level. This process produced a set of 27 smoothed digit-position functions for each language version of GDTT. Across digit functions, the mean SRT was -12.8 dB in the Asante-Twi (range from -15.7 to -8.8 dB) and the Ghanaian English (range from -15.5 to -9.7 dB) versions, while the slope was 19.2%/dB in Asante-Twi and 22.0%/dB in Ghanaian English (the slopes varied by a factor of about 2.4%/dB across digit functions in each version).

To harmonize the difficulty levels among digits in triplets and test lists, the stimuli were attenuated or amplified to equalize the 27-digit functions based on the mean SNR for 80%-digit recognition

(-10.8 dB in Asante-Twi and -11.0 dB in Ghanaian English). This target was selected because the final test aimed to measure the SRT at the 50% recognition point for all triplets, which is expected to occur near the 80% recognition point for single digits (Akeroyd et al., 2015). To reach this target, the level adjustment range was -4.1 to 3.1 dB across digit functions in Asante-Twi and -4.4 to 3.3 dB in Ghanaian English.

Phase 2 – Normative Data and List Equivalence

An adaptive procedure was used for the first part of Phase 2 testing. It followed a one-up one-down method with 4-dB step sizes until the first incorrect response or a reversal was observed, and then a 2-dB step size afterwards. The first-digit triplet was presented at 65 dBA (SNR = 0 dB), and the speech-shaped noise was maintained at a constant level of 65 dBA during the testing process for each language version. Scoring was achieved at the triplet level, requiring that all three digits in a triplet be identified correctly and in their correct order. Three lists of 27-digit triplets for each language version of the GDTT were presented to the participants. The order of the lists was counterbalanced. Thirty-two (32) participants were tested with the Asante-Twi version (comprising 16 participants each in the native and non-native speaker groups) and thirty-two (32) participants with the Ghanaian English version. Each participant's SRT corresponded to the presentation level where 50% of correct responses were achieved between the fifth and 27th triplets.

One-way analyses of variance were conducted to assess the effects of list number (i.e., list equivalence) and list order (i.e., differences between 1st vs. 2nd vs. 3rd presentation) for the three lists in each version of the GDTT using the data obtained with the adaptive procedure. The list equivalence assessment determined if the list number posed equal challenges or represented the same auditory difficulty level. Additional analyses explored the impact of list order (LO) on test performance and whether learning or practice effects were linked to the presentation sequence.

For the Ghanaian English version, the effect of the list number was not significant [$F(2, 95) = 0.711$, $p = 0.49$] with an average SRT of -11.4 dB (SD = 0.66 dB) across the three lists. However, a statistically significant difference was observed for the list order [$F(2, 95) = 4.22$, $p = 0.018$]. A Tukey HSD post-hoc test (Table 2) identified a significant difference between the mean SRTs of the first and third list (LO1 vs. LO3), but no significant difference between the mean SRTs of the first and second (LO1 vs. LO2) or second and third (LO2 vs. LO3) list presentation.

Table 2. Multiple comparisons of adaptive data of GDTT English list order using the Tukey HSD test.

(I)Type of List Order	(J)Type of List Order	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
LO1	LO2	0.24063	0.15706	0.314	-0.1501	0.6313
	LO3	0.45625*	0.15706	0.018	0.0655	0.8470
LO2	LO1	-0.24063	0.15706	0.314	-0.6313	0.1501
	LO3	0.21562	0.15706	0.393	-0.1751	0.6063
LO3	LO1	-0.45625*	0.15706	0.018	-0.8470	-0.0655
	LO2	-0.21562	0.15706	0.393	-0.6063	0.1751

*. The mean difference is significant at the 0.05 level.

For the Asante-Twi version, the ANOVA results indicated no significant difference in SRT for list number for both native [$F(2, 47) = 0.62$, $p = 0.54$] and non-native [$F(2, 47) = 0.06$, $p = 0.94$] speaker groups. List order also did not significantly impact results for either native speakers [$F(2, 47) =$

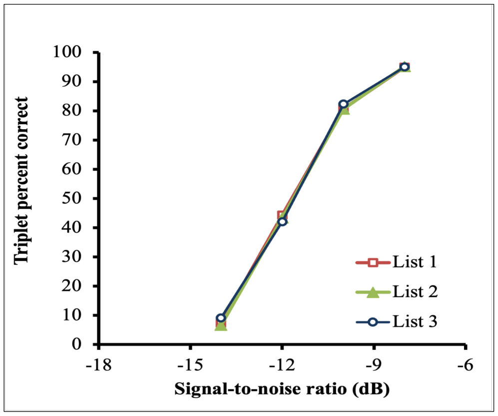
0.43, $p = 0.65$] or non-native speakers [$F(2, 47) = 1.15$, $p = 0.33$]. Descriptive statistics revealed that the native speaker group ($n = 16$) had a mean SRT of -11.34 dB (SD = 0.48 dB), while the non-native group ($n = 16$) had a mean SRT of -11.33 dB (SD = 0.52 dB) over the 3 lists. An independent sample t-test was conducted to compare the SRTs, averaged over the 3 lists, for both native and non-native speakers. The results revealed there was no statistically significant difference in the performance of the native and non-native speaker groups ($t = 0.06$, df = 30, $p = 0.971$, 2-tailed at 0.05 alpha level).

Measures at fixed SNRs were conducted in the second part of Phase 2 to estimate the slope of the triplet psychometric functions utilizing the same participants of the first part of Phase 2. The speech-shaped noise level was maintained at a constant 65 dBA, while the presentation level of the digit triplets was adjusted to four predetermined SNRs (-14, -12, -10, and -8 dB). Half of the participants were tested using an ascending sequence of SNRs (e.g., the first list presented at the SNR of -14 dB, the second list at the SNR of -12 dB, the third list at the SNR of -10 dB, etc.), and the other half were tested using a descending sequence of SNRs. The list order was counterbalanced across the SNR sequences and participants.

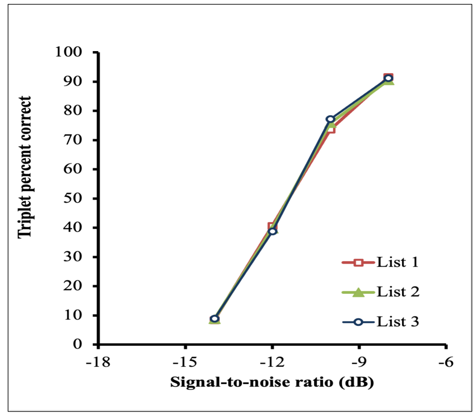
The triplet recognition score obtained at each SNR was used to plot the psychometric functions for each list of the GDTT (see Figure 3). The average slopes obtained for each list for both test versions are reported in Table 3. As can be observed, the functions exhibit a sharp steepness and overlap across the three lists for each language version of the test. The average slope of the triplet recognition function for Asante-Twi was 17.9%/dB and 19.4%/dB for the Ghanaian English version. This was achieved by interpolating the SNR at which 50% correct recognition of the fixed data (-11.4 dB for Asante-Twi, and -11.6 dB and -11.7 dB for Ghanaian English for trial less than a list and greater than or equal to a list. respectively).

Figure 3. Psychometric functions for each list of the GDTT

Ghanaian English



Asante-Twi



Discussion

This paper aimed to outline the procedures for the development of the GDTT featuring digit triplets in Asante-Twi and Ghanaian English. The same test construction procedure was used for both language versions; following the International Collegium of Rehabilitative Audiology (ICRA) guidelines (Akeroyd et al., 2015).

Overall, when using the adaptive procedure, the GDTT demonstrated high consistency across both languages, the mean SRT obtained for both language versions are -11.3 dB and -11.4 dB for Asante-Twi and Ghanaian English, respectively. These SRT values closely align with that reported for the Dutch version (-11.2 dB) and are within ± 2 dB of the Canadian version (English and French; -12.1 to -12.7 dB) (Giguère et al., 2020), the European French (-10.5 dB; Jansen et al., 2010) and Polish versions (-9.4 dB, Ozimek et al., 2009). This close comparison in the SRTs obtained with the GDTT with other language versions can be attributed to factors such as test arrangements, speech stimulus recording and selection, articulation precision, and test methodology.

The slope of the psychometric functions obtained for each of the three lists using the fixed-level method was steep. The average slope/triplet recognition function was 17.9%/dB for the Asante-Twi version of the GDTT and 19.4%/dB for the Ghanaian English. These slope values are within the range of those reported for other versions of the DTT (Van den Borre et al., 2021; Zokoll et al., 2012, 2013) but lower than those obtained, for example, for the European French (27.1 %/dB, Jansen et al., 2010) and the Canadian English version (male) (26.9 %/dB, Giguère et al., 2020). These differences in the slope values can be attributed to factors such as linguistic, phonetic, and cultural variations (Ozimek et al., 2009; Warzybok et al., 2016; Zokoll et al., 2012). Steep triplet recognition slopes make it easy to compare results across languages/dialects by considering and adjusting for test specific SRT norms (Giguère et al., 2020).

The statistical analyses for the Ghanaian English lists using the adaptive procedure show no list number effect, implying list equivalence. However, an effect of the list presentation order was found. The Tukey post hoc tests indicated a significant difference in the mean SRT between the first and third (Table 2). Overall, participants' SRTs improved progressively from the first list to the third list, indicating a learning effect. This finding suggests the importance of sufficient training and practice before administering the Ghanaian English test to overcome the impact of the learning effect. Consequently, for the normative data for the Ghanaian English test, two sets of norm values are suggested. In screening scenarios where time constraints limit trial testing/training before actual screening to less than a triplet list, the average SRT of the first and second list order (LO1 and LO2 = -11.1 dB) should be used as the norm values (Table 3). Conversely, for participants receiving trial or practice sessions covering at least one triplet list, the average SRT of the second and third list orders (LO2 and LO3 = -11.4 dB) should serve as the norm value (Table 3). This approach would ensure an accurate assessment and interpretation of participants' performance based on their level of exposure to the test materials.

Table 3. Suggested normative values for the GDTT.

Version	**Adaptive SRT**		
	Lists	**Mean (dB)**	**SD**
Ghanaian English (≥ one trial list)	2-3	-11.4	0.66
Ghanaian English (< one trial list)	1-2	-11.1	0.62
Asante-Twi	1-3	-11.3	0.67

The statistical analyses conducted for the Asante-Twi version of the GDTT revealed no differences in the list number or list order in the native or non-native speakers. These results suggest that the lists are equivalent in terms of difficulty and that there is no sign of a learning effect. The latter indicates that performance does not change over the first, second, or third list presented for neither group. Similarly, results from an independent sample t-test showed no statistically significant difference in the SRTS average over the 3 lists for both the native and non-native speakers. In effect, the Asante-Twi DTT is linguistically appropriate for the Ghanaian population for the promotion of hearing screening without introducing language-related differences.

While this study provides valuable insights into the development and evaluation of the GDTT, it is important to acknowledge certain limitations. Firstly, the sample size of the study, while sufficient for the initial evaluation, may not fully represent the diversity of the Ghanaian population. Future studies could benefit from a larger and more diverse sample to validate the GDTT and enhance the generalizability of the results. Additionally, the study focused on adults, and the applicability of the GDTT to other age groups, especially children, remains an area for further investigation.

The development of the GDTT marks an initial step in improving access to hearing screening in resource-limited settings in Ghana. Its key advantage is that it an automated hearing screening test, requiring neither trained personnel nor a specialized environment for administration. This enables individuals to take the test independently with minimal support.

The GDTT would facilitate early identification, and foster data on the prevalence of hearing loss in Ghana from the local to district level, then to regional, and national-level statistics (Adadey et al., 2017). Such data is essential for public health planning, enabling policymakers to allocate resources efficiently, implement targeted interventions, and formulate comprehensive strategies to address hearing health on a national scale. To facilitate this process, initiatives can focus on integrating the GDTT into routine healthcare checks within the Ghanaian healthcare system. This integrated approach would collectively enhance access to hearing healthcare, increase awareness, and facilitate early identification. Those identified with signs of hearing loss through the GDTT could be referred to trained personnel for further evaluation, thus ensuring targeted, efficient resource allocation, and expanding access to hearing healthcare services.

Conclusion

This paper outlines the development of the GDTT, a Ghanaian version of the digit triplet test, with normative data for adults aged 18 and above. Available in both Asante-Twi and Ghanaian English, with a single talker option (female) for both language versions, the test construction adheres to international guidelines. Results revealed comparable performance patterns in SRT and slope consistency across both language versions of GDTT. Notably, a list order effect was identified in the Ghanaian English version, suggesting a potential need for pre-test training to ensure reliable results. The statistical characteristics in each language version were comparable to findings from digit triplet tests developed in other languages or dialects. The development of a population-specific screening test is essential to address the linguistic and cultural factors that may influence hearing screening outcomes. The GDTT represents an initial step towards improving access to hearing screening services for the Ghanaian population.

Acknowledgement

The authors would like to thank the speaker who read the speech stimuli, all participants for their participation, and the staff of the Centre for Hearing and Speech Services for their willingness to allow the use of their facility and the support they provided.

Declaration of Interest

The authors declare no potential conflicts of interest concerning this article's compilation, authorship, and/or publication. The authors are responsible for the content and writing of the article.

Reference

Adadey, S. M., Awandare, G., Amedofu, G. K., & Wonkam, A. (2017). Public health burden of hearing impairment and the promise of genomics and environmental research: A case study in Ghana, Africa. *OMICS A Journal of Integrative Biology*, *21*(11), 633–637. https://doi.org/10.1089/omi.2017.0145

Adika, G. S. K. (2012). English in Ghana: Growth, tensions, and trends. *International Journal of Language, Translation and Intercultural Communication*, *1*, 151. https://doi.org/10.12681/ijltic.17

Agbozo, G. E. (2015). *Language choice in Ghanaian classrooms: Linguistic realities and perceptions*. Norwegian University of Science and Technology.

Akeroyd, M. A., Arlinger, S., Bentler, R. A., Boothroyd, A., Dillier, N., Dreschler, W. A., Gagné, J. P., Lutman, M., Wouters, J., Wong, L., & Kollmeier, B. (2015). International Collegium of Rehabilitative Audiology (ICRA) recommendations for the construction of multilingual speech tests. *International Journal of Audiology*, *54*, 17–22. https://doi.org/10.3109/14992027.2015.1030513

Akotey, S. C., Fynn, J. A., Danful, G. K., Offei, Y. N., & Amedofu, G. K. (2023). Development of audiology in Ghana: past, present, and future. *International Journal of Audiology*. https://doi.org/10.1080/14992027.2023.2263813

American Speech-Language-Hearing Association (n.d.). *Adult Hearing Screening* (Practice Portal). Retrieved month, day, year, from www.asha.org/Practice-Portal/Professional-Issues/Adult-Hearing-Screening/

Appiah, S. O., & Ardila, A. (2020). The question of school language in multilingual societies: The example of Ghana. *RUDN Journal of Psychology and Pedagogics*, *17*(2), 263–272. https://doi.org/10.22363/2313-1683-2020-17-2-263-272

Cameron, S., Glyde, H., Dillon, H., Whitfield, J., & Seymour, J. (2016). The Dichotic Digits difference Test (DDdT): Development, normative data, and test-retest reliability studies part 1. *Journal of the American Academy of Audiology*, *27*(6), 458–469. https://doi.org/10.3766/jaaa.15084

Çetinkaya, Ü. C., & Konukseven, Ö. (2023). Development of a smartphone-based Turkish digits in noise test. *Egyptian Journal of Otolaryngology*, *39*(1). https://doi.org/10.1186/s43163-023-00511-2

Dillon, H., Beach, E. F., Seymour, J., Carter, L., & Golding, M. (2016a). Development of telscreen: A telephone-based speech-in-noise hearing screening test with a novel masking noise and scoring procedure. *International Journal of Audiology*, *55*(8), 463–471. https://doi.org/10.3109/14992027.2016.1172268

Fagan, J. J., & Jacobs, M. (2009). Survey of ENT services in Africa: Need for a comprehensive intervention. *Global Health Action*, *2*(1), 1–7. https://doi.org/10.3402/gha.v2i0.1932

Folmer, R. L., Vachhani, J., McMillan, G. P., Watson, C., Kidd, G. R., & Patrick, F. M. (2017). Validation of a computer-administered version of the digit-in-boise test for hearing screening in the United States. *J Am Acad Audiol.*, *28*(2), 161–169. https://doi.org/10.3766/jaaa.16038

Gates, G. A., Cobb, J. L., Linn, R. T., Rees, T., Wolf, P. A., & D'Agostino, R. B. (1996). Central auditory dysfunction, cognitive dysfunction, and dementia in older people. *Arch Otolaryngol Head Neck Surg.*, *122*, 161–167.

Ghana Statistical Service (GSS). (2021). *Ghana 2021 population and housing census - General report volume 3D: Literacy and education* (Vol. 3D). https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3D_Literacy and Education.pdf

Giguère, C., Lagacé, J., Ellaham, N. N., Pichora-Fuller, M. K., Goy, H., Bégin, C., Alary, É., & Bowman, R. (2020). Development of the Canadian digit triplet test in English and French. *The Journal of the Acoustical Society of America*, *147*(3), EL252–EL258. https://doi.org/10.1121/10.0000825

Huddle, M. G., Goman, A. M., Kernizan, F. C., Foley, D. M., Price, C., Frick, K. D., & Lin, F. R. (2017). The economic impact of adult hearing loss: A systematic review. In *JAMA Otolaryngology - Head and Neck Surgery* (Vol. 143, Issue 10, pp. 1040–1048). American Medical Association. https://doi.org/10.1001/jamaoto.2017.1243

Jamaluddin, S. A. (2016). Development and evaluation of the digit triplet and auditory-visual matrix sentence tests in Malay [University of Canterbury]. In *University of Canterbury*. https://doi.org/10.3813/AAA.918988

Jansen, S., Luts, H., Dejonckere, P., Van Wieringen, A., & Wouters, J. (2013). Efficient hearing screening in noise-exposed listeners using the digit triplet test. *Ear and Hearing*, *34*(6), 773–778. https://doi.org/10.1097/AUD.0b013e318297920b

Jansen, S., Luts, H., Dejonckere, P., Van Wieringen, A., & Wouters, J. (2014). Exploring the sensitivity of speech-in-noise tests for noise-induced hearing loss. *International Journal of Audiology*, *53*(3), 199–205. https://doi.org/10.3109/14992027.2013.849361

Jansen, S., Luts, H., Wagener, K. C., Frachet, B., & Wouters, J. (2010). The French digit triplet test: A hearing screening tool for speech intelligibility in noise. *International Journal of Audiology*, *49*(5), 378–387. https://doi.org/10.3109/14992020903431272

King, S. M. (2010). *Development and evaluation of a new Zealand digit triplet test for auditory screening*. University of Canterbury.

Lin, F. R., Metter, E. J., O'brien, R. J., Resnick, S. M., Zonderman, A. B., & Ferrucci, L. (2011). Hearing loss and incident dementia. *Arch Neurol*, *68*(2), 214–220. http://www.r-project

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., Cooper, C., Costafreda, S. G., Dias, A., Fox, N., Gitlin, L. N., Howard, R., Kales, H. C., Kivimäki, M., Larson, E. B., Ogunniyi, A., … Mukadam, N. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet commission. In *The Lancet* (Vol. 396, Issue 10248, pp. 413–446). Lancet Publishing Group. https://doi.org/10.1016/S0140-6736(20)30367-6

McDaid, D., Park, A. La, & Chadha, S. (2021). Estimating the global costs of hearing loss. *International Journal of Audiology*, *60*(3), 162–170. https://doi.org/10.1080/14992027.2021.1883197

Mulwafu, W., Ensink, R., Kuper, H., & Fagan, J. (2017). Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015. *Global Health Action*, *10*(1). https://doi.org/10.1080/16549716.2017.1289736

Oremule, B., Abbas, J., Saunders, G., Kluk, K., Isba, R., Bate, S., & Bruce, I. (2024). Mobile audiometry for hearing threshold assessment: A systematic review and meta-analysis. *Clinical Otolaryngology*, *49*(1), 74–86. https://doi.org/10.1111/coa.14107

Ozimek, E., Kutzner, D., Sek, A., & Wicher, A. (2009). Development and evaluation of Polish digit triplet test for auditory screening. *Speech Communication*, *51*(4), 307–316. https://doi.org/10.1016/j.specom.2008.09.007

Paster, M. (2011). The verbal morphology and phonology of Asante Twi. *Studies in African Linguistics*, *39*(1).

Pérez-González, P., Gorospe Arocena, J., & Lopez Poveda, E. (2013). A Castilian Spanish digit triplet identification test for assessing speech intelligibility in quiet and in noise. *Revista de Acústica*, *44*(3), 13–24.

Potgieter, J. M., Swanepoel, D. W., Myburgh, H. C., Hopper, T. C., & Smits, C. (2016). Development and validation of a smartphone-based digits-in-noise hearing test in South African English. *International Journal of Audiology*, *55*(7), 405–411. https://doi.org/10.3109/14992027.2016.1172269

Sarant, J., Harris, D., Busby, P., Maruff, P., Schembri, A., Lemke, U., & Launer, S. (2020). The effect of hearing aid use on cognition in older adults: Can we delay decline or even improve cognitive function? *Journal of Clinical Medicine*, *9*, 2–23.

Smits, C., Kapteyn, T. S., & Houtgast, T. (2004). Development and validation of an automatic speech-in-noise screening test by telephone. *International Journal of Audiology*, *43*(1), 15–28. https://doi.org/10.1080/14992020400050004

Stam, M., Smit, J. H., Twisk, J. W. R., Lemke, U., Smits, C., Festen, J. M., & Kramer, S. E. (2016). Change in psychosocial health status over 5 years in relation to adults' hearing ability in noise. *Ear and Hearing*, *37*(6), 680–689. https://doi.org/10.1097/AUD.0000000000000332

Uhlmann, R. F., Larson, E. B., Rees, T. S., Koepsell, T. D., & Duckert, L. G. (1989). Relationship of hearing impairment to dementia and cognitive dysfunction in older adults. *Journal of the American Medical Association*, *261*(13), 1916–1919.

Van den Borre, E., Denys, S., van Wieringen, A., & Wouters, J. (2021). The digit triplet test: A scoping review. In *International Journal of Audiology* (Vol. 60, Issue 12, pp. 946–963). Taylor and Francis Ltd. https://doi.org/10.1080/14992027.2021.1902579

Ventry, I. M., & Weinstein, B. E. (1982). The hearing handicap inventory for the elderly: A new tool. *Ear and Hearing*, *3*(3), 128–134. https://doi.org/10.1097/00003446-198205000-00006

Vlaming, M. S. M. G., MacKinnon, R. C., Jansen, M., & Moore, D. R. (2014). Automated screening for high-frequency hearing loss. *Ear & Hearing*, *35*, 667679.

Wagener, K. C., Bräcker, T., Brand, T., & Kollmeier, B. (2006). Evaluation des Ziffern-Tripel-Tests über Kopfhörer und telefon. *DGA Jahrestagung*, 1–4.

Wang, S., & Wong, L. L. N. (2023). Development of the Mandarin digit-in-noise test and examination of the effect of the number of digits used in the test. *Ear & Hearing*. https://doi.org/10.1097/AUD.0000000000001447

Warzybok, A., Zokoll, M. A., & Kollmeier, B. (2016). Development and evaluation of the Russian digit triplet test. *Acta Acustica United with Acustica*, *102*(4), 714–724. https://doi.org/10.3813/AAA.918988

Watson, C. S., Kidd, G. R., Miller, J. D., Smits, C., & Humes, L. E. (2012). Telephone screening tests for functionally impaired hearing: Current use in seven countries and development of a US version. *Journal of the American Academy of Audiology*, *23*(10), 757–767. https://doi.org/10.3766/jaaa.23.10.2

Williams-Sanchez, V., McArdle, R. A., Wilson, R. H., Kidd, G. R., Watson, C. S., & Bourne, A. L. (2014). Validation of a screening test of auditory function using the telephone. *Journal of the American Academy of Audiology*, *25*(10), 937–951. https://doi.org/10.3766/jaaa.25.10.3

World Health Organization. (2021). *Hearing screening considerations for implantation*. https://doi.org/CC BY-NC-SA3.0 IGO

Zhang, M., Bi, Z., Fu, X., Wang, J., Ruan, Q., Zhao, C., Duan, J., Zeng, X., Zhou, D., Chen, J., & Bao, Z. (2019). A parsimonious approach for screening moderate-to-profound hearing loss in a community-dwelling geriatric population based on a decision tree analysis. *BMC Geriatrics*, *19*(1). https://doi.org/10.1186/s12877-019-1232-x

Zokoll, M. A., Hochmuth, S., Warzybok, A., Wagener, K. C., Buschermöhle, M., & Kollmeier, B. (2013). Speech-in-noise tests for multilingual hearing screening and diagnostics. *American Journal of Audiology*. https://doi.org/10.1044/1059-0889(2013/12-0061)

Zokoll, M. A., Wagener, K. C., Brand, T., Buschermöhle, M., & Kollmeier, B. (2012). Internationally comparable screening tests for listening in noise in several European languages: The German digit triplet test as an optimization prototype. *International Journal of Audiology*, *51*(9), 697–707. https://doi.org/10.3109/14992027.2012.690078

CHAPTER 5

Validation of the Ghanaian Digit Triplet Test for Hearing Screening in Ghana

*Sesi Collins Akotey, Josée Lagacé, Christian Giguère, Katrine Sauvé-Schenk,

School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, 200 Lees Avenue, Ottawa, Ontario K1N 6N5, Canada.

To be submitted to Ear and Hearing Journal

Author contribution:

Sesi Collins Akotey: Conceived the idea for the paper, developed its framework, sought and obtained the necessary ethical clearances, conducted data collection and analysis, and was the primary author responsible for drafting and revising the manuscript.

Josee Lagacé, Karine Sauvé-Schenk, and Christian Giguère: Provided critical editorial input and expert guidance throughout the development of the paper. As members of the corresponding author’s thesis advisory committee, they offered supervision, ensured the study adhered to academic and research standards, and contributed to refining the manuscript for publication.

Abstract

Background**:** Hearing loss is a significant global public health concern, affecting individuals of all ages and backgrounds. In Ghana, like many other countries, hearing loss poses a considerable burden on individuals, families, and the society. Early detection of hearing loss via hearing screening is a key step to curbing the adverse effects of hearing loss, particularly in adults, and the Digit triplet test is a promising hearing screening option. ***Objective****:* This study aimed to evaluate the performance of the Asante-Twi and Ghanaian English versions of the Digit Triplet Test (GDTT) for hearing screening among Ghanaians. ***Methods*****:** Ninety participants underwent GDTT testing, audiometric testing and completed the Asante-Twi adapted version of the Revised Hearing Handicap Inventory Screening Tool (RHHI-S). ***Results*****:** Overall, RHHI-S scores positively correlated with hearing loss classification (pure tone average) and diotic speech recognition threshold results for both language versions of the GDTT. For a hearing criterion of an average of four frequencies from 0.5 to 4 kHz > 25-, 30-, 35-, and 40-dB HL, the area under the receiver operating curve (AUC) for GDTT tests was 0.92, 0.97, 0.98, and 0.97, respectively. ***Conclusion:*** Receiver operating characteristic analysis demonstrated the accuracy of the GDTT in distinguishing between positive and negative hearing loss cases. Early identification of hearing loss facilitated by the GDTT could lead to timely interventions and improve hearing health outcomes for adults in Ghana, ultimately reducing the burden of hearing loss on individuals and society.

Keywords: Digit triplet, Asante-Twi, Ghanaian English, Hearing screening.

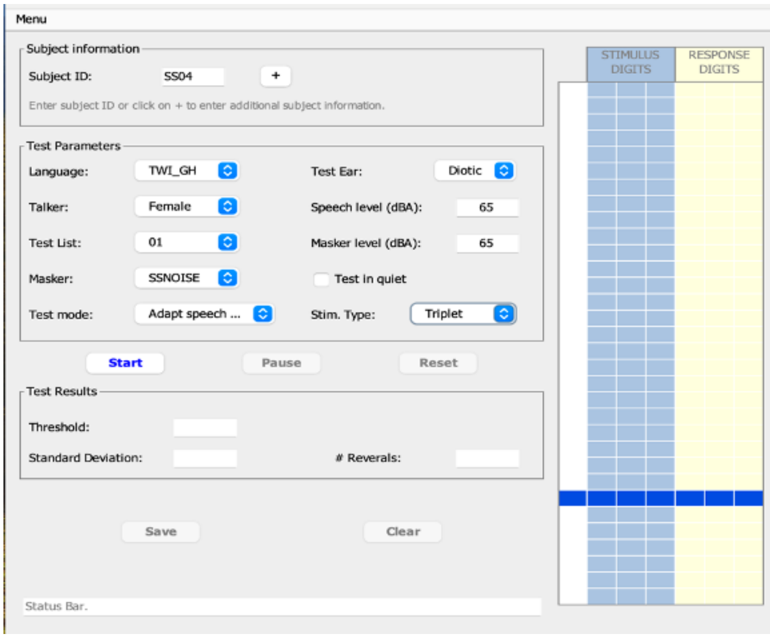
Introduction

Hearing loss is a major public health issue globally, affecting individuals of all ages and spanning various socio-economic and cultural backgrounds. The impact of hearing loss can be profound, affecting communication, social interaction, education, employment opportunities, and overall quality of life. The challenges associated with hearing health in low-income countries are exacerbated by the lack of sufficient access to hearing health facilities and a shortage of qualified personnel (Akotey et al., 2023; Mulwafu et al., 2017), meaning that individuals may struggle to reach essential services. Addressing the challenges posed by hearing loss requires a comprehensive strategy that prioritizes early identification and access to appropriate interventions. Early detection of hearing loss via hearing screening is an essential first step in curbing the adverse effects of hearing loss, particularly in adults. Implementing hearing screening methods that require few resources, such as the Digit Triplet Test, may help overcome the accessibility and resource-limited challenges.

In 2004, Smits and colleagues developed a test based on a recall of digit triplet in Dutch that people could self-administer over the telephone (Smits et al., 2004). The Dutch test gained significant public interest and participation after its implementation and became known as the Dutch National Hearing Test (Van den Borre et al., 2021). The test determines speech reception threshold (SRT), which is the signal-to-noise ratio (SNR) required for an individual to correctly identify 50% of triplets (Smits et al., 2004; Van den Borre et al., 2021). The test is a robust speech-in-noise hearing screening tool with a strong correlation with pure tone average (PTA) thresholds (Smits et al., 2004; Van den Borre et al., 2021). The test can be delivered through the telephone, computer, and smartphone or tablet (Folmer et al., 2017; Potgieter et al., 2016; Smits et al., 2004, 2006; Van den Borre et al., 2021). These qualities make the test a valuable and easily accessible tool for hearing screening. The success of the Dutch test has prompted extensive research in speech-in-noise hearing screening. As a result, the test has been adapted into several languages, including American English, Australian-English, and South African English, Danish, French, Polish, Flemish, German, Swedish, and Greek, as well as Canadian French and English (Giguère et al., 2020; Jansen et al., 2010; Potgieter et al., 2016; Van den Borre et al., 2021; Zokoll et al., 2013), and it is generally referred to as the Digit Triplet Test (DTT).

Recently, Akotey et al. (n.d. submitted) developed a Ghanaian version of the Digit Triplet Test (GDTT), which included two language sets of recordings: Asante-Twi and Ghanaian English. The International Collegium of Rehabilitative Audiology guidelines (Akeroyd et al., 2015) were followed for the creation of the GDTT. The test uses the cross-platform Java application that was created for the Canadian version of the DTT (see Giguère et al., 2020 for more details). The platform can run on any major operating system (e.g., Windows, Mac OS, or Linux). The software configuration allows the tester to hide the main interface to prevent participants from seeing the stimulus digits while running the GDTT. The testing interface provides a user-friendly display for managing various aspects of the test (Figure 1). It incorporated controls for participant information, test parameter selection such as running tests (in Ghanaian English or Asante-Twi; diotic, antiphase mode; fixed or adaptive testing procedure), and saving test results.

Figure 1:Testing interface of the GDTT.



As shown in Figure 2, an external USB numeric keypad (Peripad-202 HW, Perixx Computer, Dusseldorf, Germany) is connected to the computer for the participants to input their responses. In addition to the testing interface, there is a stimulus-response digit table to update the operator on the participant’s response and progress throughout the test. To ensure comprehensive data management, Excel files are included in the software to store application settings, list definitions, default test parameters, calibration values, and test results. This configuration facilitated accurate and efficient organization and retrieval of data.

Figure 2: Set-up for GDTT testing.

An adaptive one-up, one-down method is used for SRT measures with the GDTT. This method follows a 4-dB step size until the first incorrect response, or a reversal is observed, and a 2-dB step size afterwards. The first-digit triplet is presented at 65 dBA (SNR = 0 dB), and the speech-shaped noise is maintained at a constant level of 65 dBA during the testing process for each language version. Scoring is achieved at the triplet level, requiring that all three digits in a triplet be identified correctly and in their correct order.

The GDTT was developed in the Hearing Research Laboratory at the University of Ottawa (Canada), and part of its evaluation was conducted at the Centre for Hearing and Speech Services in Winneba (Ghana). Details on the GDTT development and psychometric properties for a normative population are found in Akotey et al. (n.d. submitted).

The objective of the current study is to validate the performance of the Ghanaian Digit Triplet Test (GDTT) for hearing screening among Ghanaian adults. The validation of the GDTT represents a significant step forward in the efforts to enhance hearing screening in Ghana. With this linguistically relevant screening tool, the study aims to facilitate its integration into routine healthcare practices and community outreach programs. While the development of the GDTT is not the answer to all the challenges surrounding access to hearing services in Ghana, it has the potential to increase awareness of hearing and hearing loss, improve early identification of hearing loss, and enhance the quality of life for individuals affected by hearing loss.

The study was approved by the Review and Ethics Board of the University of Ottawa, Canada; the Korle Bu Teaching Hospital Scientific and Technical Committee/Institution Review Board, Accra, Ghana; the Komfo Anokye Teaching Hospital Institutional Review Board, Kumasi, Ghana; and approval from the Centre for Hearing and Speech Services, Winneba, Ghana.

Methods and materials

A cross-sectional, multi-site study with participants recruited from three audiological facilities in three regions of Ghana: the Centre for Hearing and Speech Services in Winneba, the Brobby Hearing Assessment Centre in Kumasi, and the Hearing Assessment Centre, Korle Bu, in Accra. A convenience, nonprobability sample method was used to recruit participants at the data collection sites. The convenience sampling approach involves choosing the nearest participant available to serve as a respondent and continuing that process until the required sample size has been obtained. Each participant was informed of the study's aim and procedure and signed a consent form prior to the experimental measures. The experimental measures included a hearing screening questionnaire, a pure tone audiometric hearing threshold, and the GDTT. Data was systematically analyzed and presented using the Statistical Package for the Social Sciences (SPSS) version 21.8. Details about the participants and each measure are described in the following sections. Participants were allowed to take some rest in between the various measures.

Participants

The study involved ninety (90) adults, speakers of Asante-Twi and Ghanaian English, between the ages of 18 and 50 years, with varying degrees of hearing acuity. However, prior to testing (RHHI-S and GDTT testing), participants were asked to indicate the language in which they would like to be tested – either Asante-Twi or Ghanaian English.

Hearing handicap screening questionnaire – RHHI-S

All participants completed the Asante-Twi version of the Hearing Handicap Inventory Screening Tool (RHHI-S) (Akotey et al., 2024; Cassarly et al., 2020) prior to the validation measures for evaluating the degree of perceived hearing handicap. Participants read the questionnaire by themselves, and the first author provided clarifications when needed.

Like the original version of the Revised Hearing Handicap Inventory Screening (RHHI-S; Cassarly et al., 2020) tool, the Asante-Twi version of the RHHI-S is a 10-item questionnaire. Each item can be answered with "No," "Sometimes," or "Yes," which corresponds to a specific score, i.e., 0 for "No," 2 for "Sometimes," and 4 for "Yes." The total score is computed and compared to a scale of hearing handicap, ranging from 0 ("no handicap") to 40 ("maximum handicap"), with a score between 0 and 8 suggesting "no hearing handicap" or a 13% probability of hearing impairment, whereas a score between 10 and 24 points suggests a 50% probability of hearing impairment. Finally, a score between 26 and 40 points indicates an 84% probability of hearing impairment (Cassarly et al., 2020).

Pure tone audiometry

Prior to the audiometric testing, participants had their ears examined with an otoscope to rule out any outer ear obstruction or infection. Audiometric testing was conducted in a sound-treated booth to measure the bilateral air conduction hearing thresholds at each octave frequency included between 0.25 and 8 kHz.

At each study site, pure tone hearing thresholds were measured by qualified audiologists using the modified Hughson-Westlake method. Diagnostic audiometers (AC 40 and GSI 61 clinical audiometers with DD45 headphones) were used for measuring the hearing thresholds of participants. Participants were briefed about the Ghanaian version of the Digit Triplet Test after the hearing threshold measure.

Validation measures of the GDTT

At each study site, the Asante-Twi or Ghanaian English versions of the GDTT were administered by the first author. The language version of the test was based on the preference indicated by the participant. All participants were tested using the adaptive method with the signal presented in the diotic condition, followed by the antiphase condition. In the diotic condition, identical signals were delivered simultaneously to both ears, representing typical binaural listening conditions. In contrast, the antiphase condition involved presenting the signal out of phase between the ears, creating a condition where the auditory cues differ, which tests the participant's ability to process spatial or binaural auditory information.

Results

Participants

The total sample was divided into two groups according to the preferred language indicated for the testing. The demographic details about the participants in the two language groups are presented in Table 1. The group labelled Asante-Twi included 45 adults with a mean age of 28 years, and the group labelled Ghanaian English included the same number of participants (45) but with a mean age of 29 years.

Table 1: Demographic statistics of participants.

Variables		Asante-Twi (n = 45)	Ghanaian English (n = 45)
		n (%)	n (%)
Age	Mean (SD)	28 (6.8)	29 (8.9)
Gender	Male	20 (44.4)	13 (28.9)
	Female	25 (55.6)	32 (71.1)

Regarding gender distribution, the Asante-Twi group consisted of 20 males (44.4%) and 25 females (55.6%), while the Ghanaian English group included 13 males (28.9%) and 32 females (71.1%). Notably, females represented a higher proportion of participants in both language groups, particularly in the Ghanaian English group.

Pure tone audiometry

The results were categorized based on the degree of hearing as determined by the pure-tone average (PTA) at four frequencies, namely 0.5, 1, 2, and 4 kHz. For each ear, the categorization included the category “normal hearing,” which included the results of all the participants with a PTA of -10 to 25 dB HL, the category “mild hearing loss,” which included the results of all the participants with a PTA of 26 to 40 dB HL; the category “ moderate hearing loss,” which included the results of all participants with a PTA of 41 to 55 dB HL; the category “moderately severe hearing loss, “ which included all the participants with a PTA of 56 to 70 dB HL, and the category “ severe-to-profound hearing loss” which included all the participants with a PTA of 71 to 91+ dB HL.

Hearing status was determined based on the results obtained at the pure tone audiometry: “bilateral normal hearing,” which included all the participants with a PTA ≤ 25 dB HL in both ears; “bilateral symmetric sensorineural hearing loss (SNHL),” which included all the participants with a PTA > 25 dB HL in both ears; “unilateral SNHL,” which included the participants with a PTA > 25 dB HL in the poorer ear and ≥ 20 dB interaural PTA difference; and “asymmetrical SNHL,” which included the participants with a PTA > 25 dB HL in both ears and an interaural PTA difference ≥20 dB.

Table 2 displays the descriptive statistics obtained at the different hearing measures with the Asante-Twi speaker group, and in Table 3 for the Ghanaian English speaker group. As reported in Table 2, 51.1% (23 participants) of the Asante-Twi speaker group had bilateral normal hearing, while 48.9% had a hearing loss in one or both ears. Specific analyses of the results obtained in the right ear reveal that 11.1% (5 participants) had a mild hearing loss, 11.1% (5 participants) a moderate hearing loss, 11.5% (5 participants) a moderately severe hearing loss, and 6.7% (3 participants) had severe-to-profound hearing loss. Analyses of the results obtained in the left ear indicate that 11.1% (5 participants) had a mild hearing loss, 6.7% (3 participants) had a moderate, 8.9% (4 participants) had a moderately severe hearing loss, and 11.1% (5 participants) had a severe-to-profound hearing loss.

In the diotic SRT category, which gauges specific auditory conditions, 55.6% were classified under "fail," while 44.4% passed the test. Similarly, the antiphase result indicates that 51.1% passed the antiphase test, while 48.9%, failed, requiring additional assessment.

Table 2: Descriptive statistics for Asante-Twi participants.

Variables	**Classification**	**Asante-Twi (n = 45)**
		N (%)
Right ear PTA	Normal hearing	27 (60.0)
	Mild hearing loss	5 (11.1)
	Moderate hearing loss	5 (11.1)
	Moderately severe hearing loss	5 (11.1)
	Severe-to-profound hearing loss	3 (6.7)
Left ear PTA	Normal hearing	28 (62.2)
	Mild hearing loss	5 (11.1)
	Moderate hearing loss	3 (6.7)
	Moderately severe hearing loss	4 (8.9)
	Severe-to-profound hearing loss	5 (11.1)
Hearing status	Bilateral normal hearing	23 (51.1)
	Bilateral symmetric SNHL	7 (15.6)
	Unilateral SNHL	9 (20.0)
	Asymmetric SNHL	6 (13.3)
RHHI-S	No hearing handicap	29 (64.4)
	50% probability of hearing impairment	11 (24.4)
	84% probability of hearing impairment	5 (11.1)
Diotic SRT	Pass	32 (71.1.)
	Fail	13 (28.9)
Antiphase SRT	Pass	23 (51.1)
	Fail	22 (48.9)

Details reported in Table 3 reveal that 37.8% of the Ghanaian English speaker group had bilateral normal hearing, while 26.7% had a bilateral symmetric sensorineural hearing loss (SNHL), 22.2% a unilateral SNHL and 13.3% an asymmetric SNHL. Specific analyses of the results obtained in the right ear reveal that 11.1% (5 participants) had a mild hearing loss, 13.3% (6 participants) a moderate hearing loss, 13.3% (6 participants) a moderately severe hearing loss and 15.6% (7 participants) with severe-to-profound hearing loss. Analyses of the results obtained in the left ear indicate that 11.1% (5 participants) had a mild hearing loss, 11.1% (5 participants) had a moderate, 20% (9 participants) a moderately severe hearing loss and 6.7% (3 participants) had a severe-to-profound hearing loss.

Table 3: Descriptive statistics for Ghanaian English participants.

Variables	**Classification**	**Ghanaian English (n = 45)**
		N (%)
Right ear PTA	Normal hearing	21 (46.7)
	Mild hearing loss	5 (11.1)
	Moderate hearing loss	6 (13.3)
	Moderately severe hearing loss	6 (13.3)
	Severe-to-profound hearing loss	7 (15.6)
Left ear PTA	Normal hearing	23 (51.1)
	Mild hearing loss	5 (11.1)
	Moderate hearing loss	5 (11.1)
	Moderately severe hearing loss	9 (20.0)
	Severe-to-profound hearing loss	3 (6.7)
Hearing status	Bilateral normal hearing	17 (37.8)
	Bilateral symmetric SNHL	12 (26.7)
	Unilateral SNHL	10 (22.2)
	Asymmetric SNHL	6 (13.3)
RHHI-S classification	No hearing handicap	22 (48.9)
	50% probability of hearing impairment	9 (20.0)
	84% probability of hearing impairment	14 (31.1)
Diotic SRT	Pass	21 (46.7)
	Fail	24 (53.7)
Antiphase SRT	Pass	19 (42.2)
	Fail	26 (57.8)

Hearing handicap screening questionnaire – RHHI-S

As indicated in Table 2, 29 participants (64.4%) of the Asante-Twi group obtained a score between 0 and 8 points on the Asante-Twi version of the RHHI-S questionnaire, which represented no hearing handicap," according to the categories of the original version of the questionnaire. Another 24.4% (11 participants) had a score between 10 and 24 points, indicating a 50% probability of hearing impairment, and 11% (5 participants) scored between 26 and 40 points, indicating an 84% probability of hearing impairment. Although most participants exhibited low to no handicap, there was a significant subset of participants (35.5%) at moderate to high risk of hearing impairment in the sample group.

For the Ghanaian English speaker group, the results obtained on the RHHI-S questionnaire indicated that 48.9% (22 participants) showed no sign of hearing handicap, while 20% (9 participants) had a 50% probability of hearing impairment. Another 31% (14 participants) obtained a result suggesting a 50% probability of hearing impairment.

Ghanaian version of the DTT (GDTT)

Preliminary data obtained with the diotic condition of the GDTT (Akotey et al., n.d. submitted) showed a mean SRT of -11.4 dB for the Ghanaian English language and -11.3 dB for the Asante-Twi. These data were used to compute the following cut-off points for screening at the 95th percentile level (mean SRT + 1.645 x standard deviation) using:

Ghanaian English cut-off = (-11.4 + [1.645 x 0.66]) = -10.3 dB

Asante-Twi cut-off = (-11.3 + [1.645 x 0.67]) = -10.2 dB.

These cut-off points were selected to ensure that only about 5% of normal hearing individuals would be categorized as “fail,” making the test less stringent and more accurate for identifying true cases of hearing loss. Speech recognition thresholds below these cut-offs were categorized as “pass” and considered as indicative of a hearing sensitivity within the normal range, while scores above the cut-off points were categorized as “fail,” requiring further assessment.

For the antiphase condition, the cut-off points were set at a threshold 6 dB better than the diotic SRT, consistent with findings from previous studies (De Sousa et al., 2020). De Sousa et al. observed that individuals with normal hearing benefit from improved speech target isolation in the antiphase condition, resulting in an antiphase SRT approximately 6 to 8 dB lower than the diotic SRT. Accordingly, the following cut-off points were established:

Ghanaian English group: Diotic SRT + 6 dB = -10.3 + 6 = -16.3 dB.

Asante-Twi group: Diotic SRT + 6 dB = -10.2 + 6 = -16.2 dB.

In the Asante-Twi speaker group, 55.6% of participants failed based on the diotic SRT results, while 44.4% passed the test. For the antiphase condition, 51.1% passed, and 48.9% failed and required further assessment. Similarly, in the Ghanaian English speaker group, 46.7% passed the diotic SRT, while 53.3% failed. For the antiphase condition, 42.2% passed, and 57.8% failed for further assessment. Overall, results from both speaker groups revealed that a substantial number of participants reported some level of hearing handicap. Additionally, the diotic and antiphase condition results highlighted the need for further assessment.

Correlation between the hearing measures

Correlation analyses were conducted with the best ear pure-tone average, namely 0.5, 1, 2, and 4 kHz, and the SRT measured with the GDTT, as well as with the results obtained at the RHHI-S scores, using the Pearson coefficient. Results of all these correlation analyses are reported in Table 4 and explained in the following paragraphs.

Pure tone hearing thresholds and RHHI-S scores

For the Asante-Twi speaker group, there was a strong correlation (0.710) between the best-ear PTA and the score obtained at the RHHI-S, with a significance level of $p < .001$ (95% CI [0.527, 0.831]). For the Ghanaian English speaker group, the correlations between the best ear PTA and the RHHI-S score were even stronger, with a coefficient correlation of 0.825 ($p < .001$, 95% CI [0.701, 0.901]).

RHHI-S score and GDTT SRT

A strong correlation of 0.658 ($p < .001$, 95% CI [0.451, 0.797]) between the RHHI-S score and the SRTs obtained in the diotic condition was observed with the Asante-Twi speaker group, as well as between the RHHI-S score and the SRT measured in the antiphase condition, with correlation coefficient of 0.694 ($p < .001$, 95% CI [0.503, 0.821]).

For the Ghanaian English group, there was also a strong and significant correlation between the RHHI-S score and SRT measured in the diotic condition, with a coefficient correlation of 0.761 ($p < .001$, 95% CI [0.602, 0.86]). The correlation between the RHHI-S score and the SRT measured in the antiphase condition for the same speaker group was 0.820 ($p < .001$, 95% CI [0.693, 0.897]).

Table 4: Relationship between hearing threshold (pure tone average) of the best ear (0.5, 1, 2, 4 kHz), RHHI-S scores, diotic and antiphase SRTs.

Language Type	**Correlation**	**Pearson correlation (*r*)**	**Significance (2-tailed)**	**95% Confidence Intervals (2-tailed)**	
				Lower	**Upper**
Asante-Twi	Hearing thresholds vs RHHI-S score	.710	<.001	.527	.831
	Hearing threshold vs diotic SRT	.784	<.001	.638	.876
	RHHI-S score vs diotic SRT	.658	<.001	.451	.797
	Antiphase SRT vs diotic SRT	.809	<.001	.675	.891
	RHHI-S score vs Antiphase SRT	.694	<.001	.503	.821
Ghanaian English	Hearing threshold vs RHHI-S score	.825	<.001	.701	.901
	Hearing threshold vs diotic SRT	.883	<.001	.796	.934
	RHHI-S score vs diotic SRT	.761	<.001	.602	.862
	Antiphase SRT vs diotic SRT	.941	<.001	.895	.968
	RHHI-S score vs Antiphase	.820	<.001	.693	.897

Pure tone hearing thresholds and GDTT SRT

The investigation of the correlations between pure tone hearing thresholds and SRTs obtained with the GDTT in the diotic condition was conducted to validate the GDTT for hearing screening, understand its comparative performance with standard audiometric tests, determine its clinical utility, and identify hearing loss patterns. Strong correlations between these measures would indicate that the GDTT can be effectively used for hearing screenings and contribute to improving hearing healthcare in Ghana.

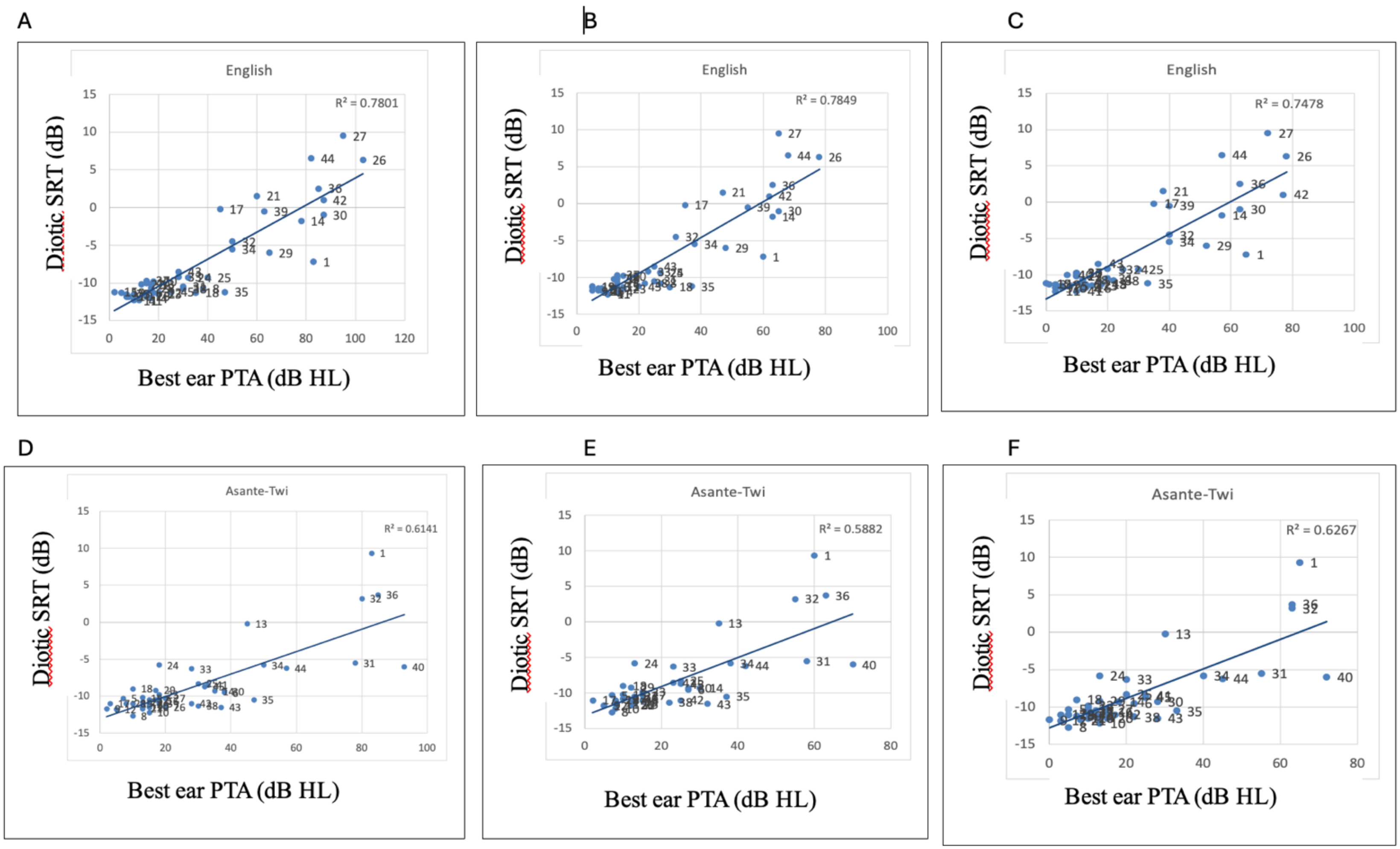
For the Asante-Twi speaking group, a significant and strong correlation of 0.784 was found between the best ear PTA and the SRT measured in the diotic condition ($p < .001$, 95% CI [0.638, 0.876]). For the Ghanaian English group, the correlation between the best PTA and the SRT measured in the diotic condition was strong, with a correlation coefficient of 0.883 ($p <.001$, 95% CI [0.796, 0.934]) (see Table 4 for details).

Similarly, Figure 3 shows the distribution of the results obtained on the GDTT with the diotic condition and best-ear PTA. Figures 3A and D illustrated audiometric pure-tone averaged thresholds for 0.5, 1, 2, and 4 kHz of the best ear plotted against SRT (presented in signal-to-noise ratio (SNR) values) obtained in the diotic condition for the Asante-Twi and Ghanaian English recordings, respectively. The trendline for these relationships showed an R^2 of 0.61 and 0.78, respectively.

On the other hand, Figures 3B and E illustrate the distribution of the audiometric PTA thresholds for 0.5, 1, and 2 kHz of the best ear plotted against the SRT obtained in the diotic condition with the Asante-Twi and Ghanaian English recordings, respectively. These relationships showed an R^2 of 0.59 and 0.79, respectively.

Finally, the distribution of the PTA thresholds for 1, 2, and 4 kHz of the best ear plotted against the SRT (presented in the diotic condition of the Asante-Twi and Ghanaian English recordings) is presented in Figures 3C and F, respectively. These relationships showed an R^2 of 0.63 and 0.75, respectively. Overall, these results suggested that the omission or inclusion of 0.5 kHz in the pure-tone average calculations does not significantly alter the relationship between PTA and GDTT SRT.

Figure 3: Relationship between GDTT diotic SRT and best ear PTA. (A). Diotic SRT, English and best ear PTA (0.5,1,2,4 kHz), (B) Diotic SRT, English and best ear PTA (0.5,1,2, kHz), (C) Diotic SRT, English and best ear PTA (1,2,4), (D) Diotic SRT, Asante-Twi and best ear PTA (0.5,1,2,4 kHz), (E) Diotic SRT, Asante-Twi and best ear PTA (0.5,1,2 kHz), (F) Diotic SRT, Asante-Twi and best ear PTA (1,2,4 kHz).



Correlations between pure tone hearing thresholds and GDTT SRT – antiphase condition

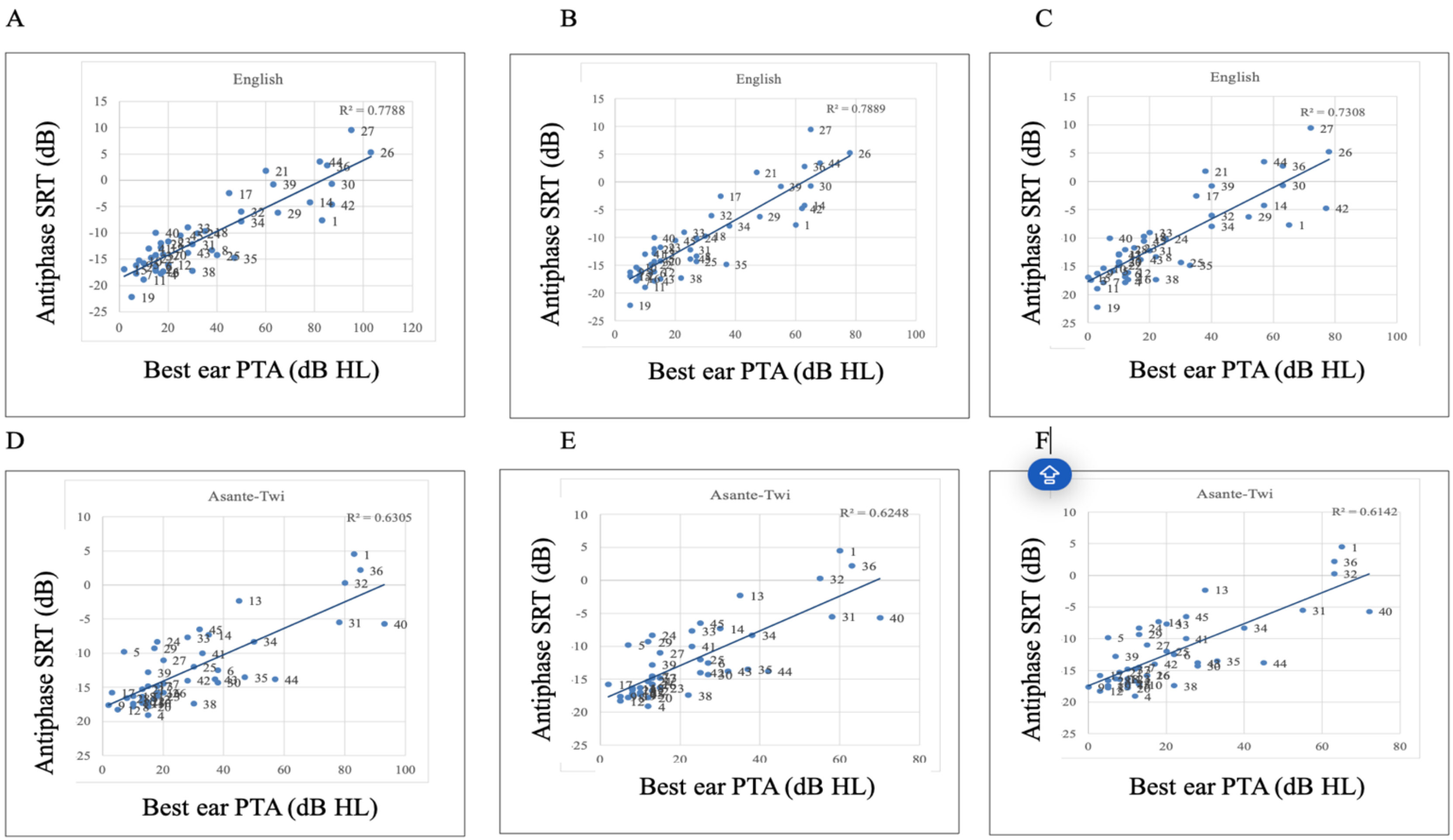
The results obtained from the GDTT for the antiphase condition were analyzed alongside the best-ear audiometric PTA thresholds at 0.5, 1, 2, and 4 kHz for both the Asante-Twi and Ghanaian English groups (Figure 4).

For the Ghanaian English group, the distribution of audiometric PTA thresholds (0.5, 1, 2, and 4 kHz) for the best ears plotted against the antiphase SRT showed an R^2 of 0.78 (Figure 4). This indicated a strong positive relationship between the PTA and the GDTT SRT in the antiphase condition. Further analysis revealed that the relationship between antiphase SRT and best ear PTA at 0.5, 1, and 2 kHz showed an R^2 of 0.68, and the correlation between antiphase SRT and best ear PTA at 1, 2, and 4 kHz was 0.58. These results suggest that the antiphase condition of the GDTT is more highly correlated to the best ear PTA thresholds averaged across 0.5, 1, 2, and 4 kHz. Notably, the inclusion of 0.5 kHz in the PTA calculations significantly enhances the correlation between PTA and GDTT SRT.

For the Asante-Twi group, the distribution (Figure 4) of audiometric PTA thresholds (0.5, 1, 2, and 4 kHz) for the best ears plotted against the antiphase SRT showed a relationship of R^2 being 0.42, indicating a moderately positive relationship. Further analysis showed that the relationship between antiphase SRT and best ear PTA at 0.5, 1, and 2 kHz showed an R^2 of 0.45, while the relationship between antiphase SRT and best ear PTA at 1, 2, and 4 kHz showed an R^2 of 0.41. These findings suggest that the antiphase condition of the GDTT is moderately sensitive to PTA thresholds at 0.5, 1, 2, and 4 kHz. Unlike the Ghanaian English group, the inclusion or exclusion of 0.5 kHz in the PTA calculations does not significantly alter the correlation between PTA and GDTT SRT for the Asante-Twi group.

The results indicated that the GDTT, in its antiphase condition, correlates differently with best ear PTA thresholds depending on the language group. For the Ghanaian English group, including 0.5 kHz in the PTA calculations is needed for maintaining a strong relationship between PTA and GDTT SRT. Conversely, for the Asante-Twi group, the inclusion of 0.5 kHz does not significantly impact the correlation. These differences highlight the importance of considering language in the development and implementation of hearing screening materials. The findings also suggest potential adjustments in the screening process to enhance accuracy and effectiveness for different population groups.

Figure 4: Relationship between GDTT antiphase SRT and best ear PTA. (A). Antiphase SRT, English and best ear PTA (0.5,1,2,4 kHz), (B) Antiphase SRT, English and best ear PTA (0.5,1,2, kHz), (C) Antiphase SRT, English and best ear PTA (1,2,4), (D) Antiphase SRT, Asante-Twi and best ear PTA (0.5,1,2,4 kHz), (E) Antiphase SRT, Asante-Twi and best ear PTA (0.5,1,2 kHz), (F) Antiphase SRT, Asante-Twi and best ear PTA (1,2,4 kHz).



Definition of hearing loss using Receiver Operating Characteristics (ROC) curves

Different receiver Operating Characteristic (ROC) curves for the GDTT diotic test for detecting hearing loss according to four definitions of hearing loss in the best ear were extrapolated (Figure 5) for averages of octave frequencies from 0.5–4 kHz > 25, > 30 dB HL, > 35 dB HL, and > 40 dB HL. These definitions were selected due to the superior correlation observed with diotic SRTs and their relevance in real-world hearing situations. For the Ghanaian English group (Table 5), the area under the ROC curve (AUC) was 0.92 for the 25 dB HL criterion, 0.97 for the 30 dB HL criterion, 0.98 for the 35 dB HL criterion, and 0.98 for the 40 dB HL best-ear criterion.

Similarly, for the Asante-Twi group (Table 6), the AUC was 0.85 for the 25 dB HL criterion, 0.95 for the 30 dB criterion, 0.98 for the 35 dB criterion, and 0.97 for the 40 dB HL best-ear criterion. The results remained consistent across each criterion.

Table 5: Definition of hearing loss by diotic SRT – Ghanaian English group.

Definition of hearing loss (0.5–4 kHz)	Area under the curve (AUC)	GDTT cut-off thresholds
> 25 dB HL	0.92	-9.7
> 30 dB HL	0.97	-9.5
> 35 dB HL	0.98	-9.5
> 40 dB HL	0.98	-9.3

Figure 5: ROC curves presenting test characteristics for diotic GDTT SRT for detecting hearing threshold PTA – best ear (A) >25 dB HL, (B) >30 dB HL, (C) >35 dB HL, and (D) >40 dB HL.

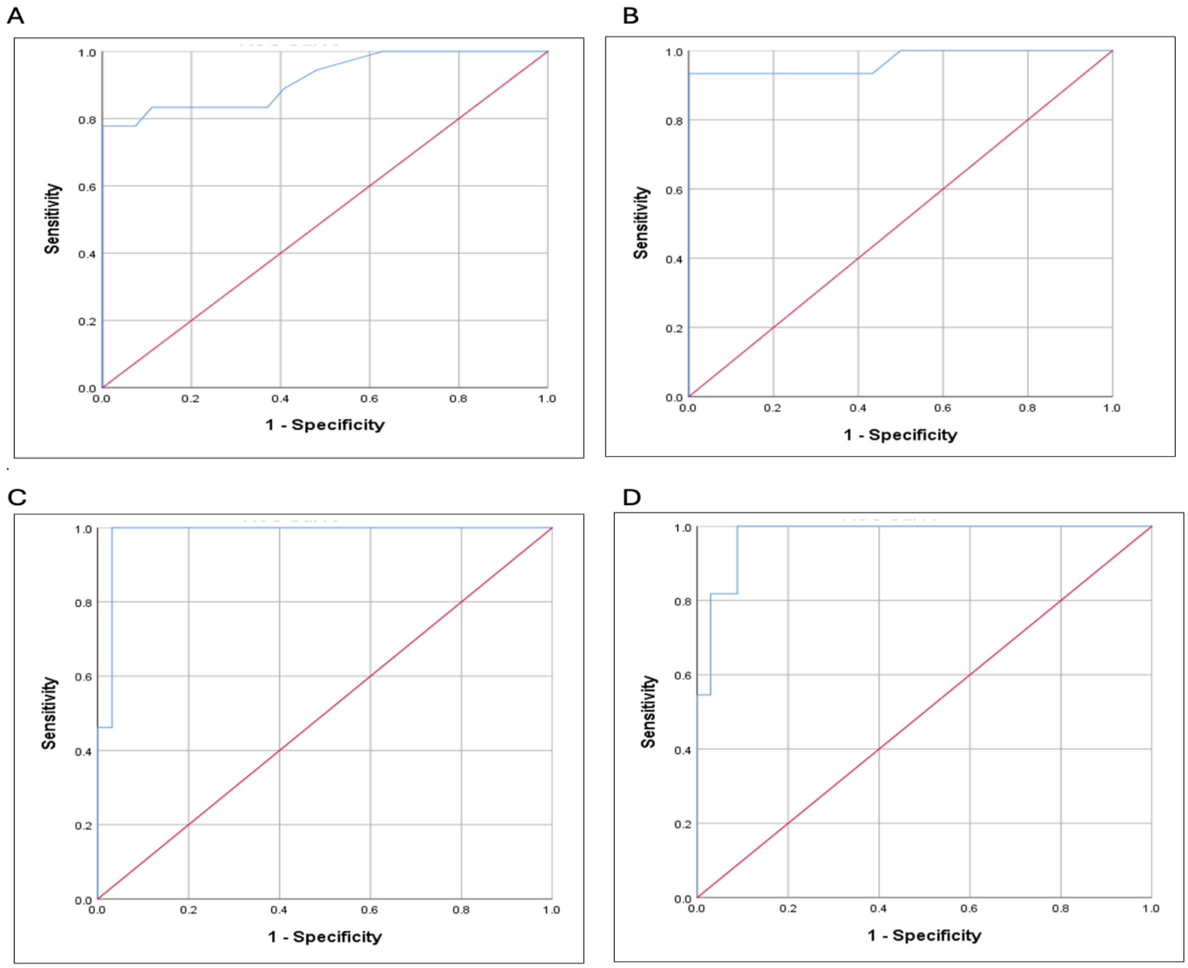


Table 6: Definition of hearing loss by diotic SRT – Asante-Twi group.

Definition of hearing loss (0.5–4 kHz)	Area under the curve (AUC)	GDTT cut-off thresholds
> 25 dB HL	0.85	-9.7
> 30 dB HL	0.95	-9.7
> 35 dB HL	0.98	-9.1
> 40 dB HL	0.97	-9.7

To evaluate the overall effectiveness of the antiphase SRT recordings in both language groups, ROC curves were drawn (Figure 6). These curves assessed the antiphase GDTT scores and pure tone average values for octave frequencies from 0.5 to 4 kHz at thresholds of >25, >30, >35, and >40 dB HL. For the Ghanaian English group (Table 7), the AUC values were 0.93 for the >25 dB HL criterion, 0.97 for the >30 dB HL criterion, 0.99 for the >35 dB HL criterion, and 0.98 for the >40 dB HL criterion, all based on the best ear response. Similarly, for the Asante-Twi group (Table 8), the AUC values were 0.88 for the >25 dB HL criterion, 0.92 for the >30 dB HL criterion, 0.93 for the >35 dB HL criterion, and 0.93 for the >40 dB HL criterion, also based on the best ear response. These high AUC values indicated that the antiphase GDTT was effective for identifying hearing loss across both language groups, with particularly strong performance at the >35 dB HL threshold. The results suggest that the antiphase GDTT can be used for hearing screening for both Ghanaian English and Asante-Twi speakers, providing a relevant method for early identification of hearing loss.

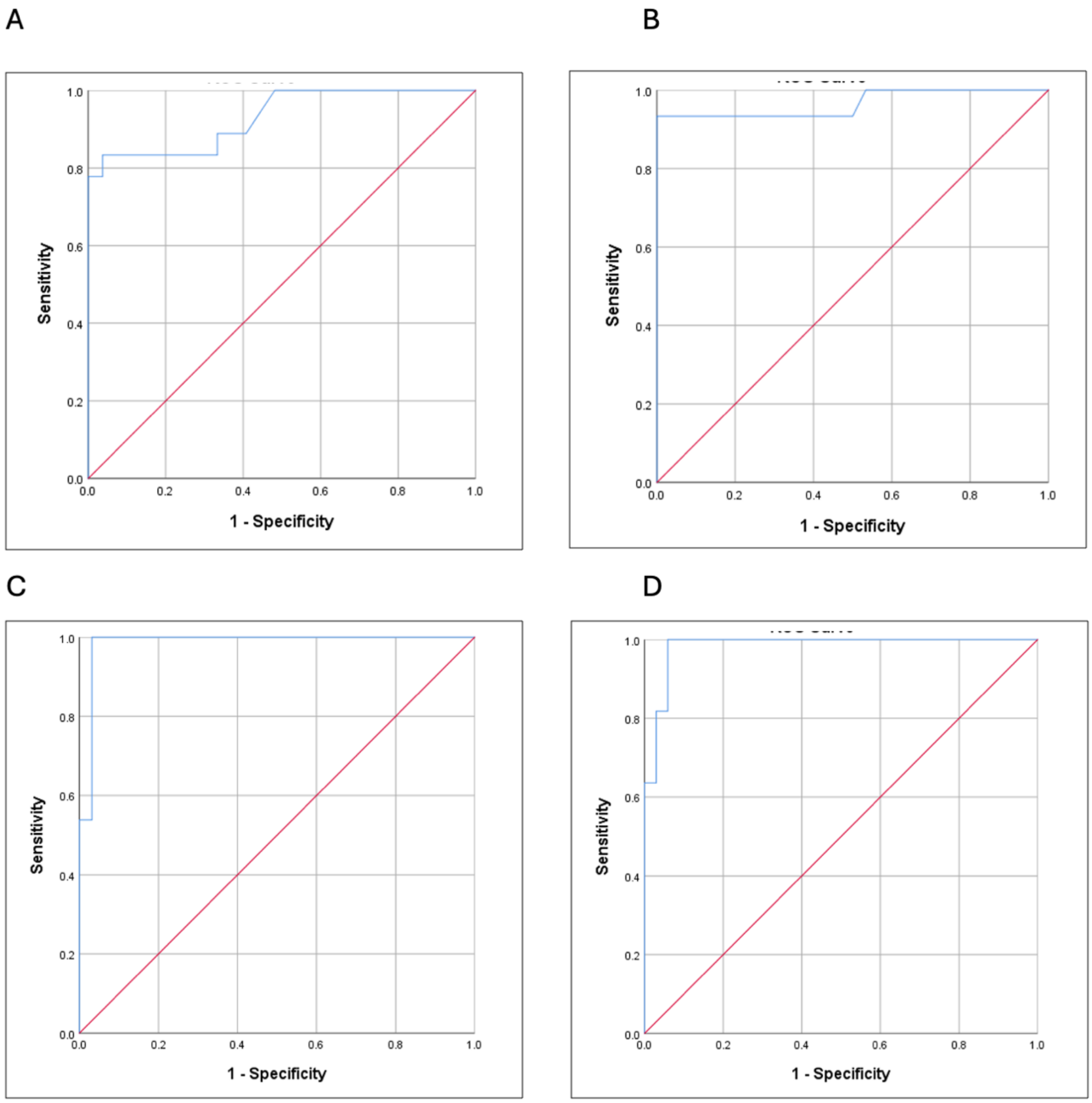
Table 7: Definition of hearing loss by antiphase SRT – Ghanaian English group.

Definition of hearing loss (0.5–4 kHz)	**Area under the curve (AUC)**	**GDTT cut-off thresholds**
> 25 dB HL	0.93	-13.55
> 30 dB HL	0.97	-13.15
> 35 dB HL	0.99	-12.50
> 40 dB HL	0.98	-13.55

Table 8: Definition of hearing loss by antiphase SRT – Asante-Twi group.

Definition of hearing loss (0.5–4 kHz)	Area under the curve (AUC)	GDTT cut-off thresholds
> 25 dB HL	0.88	-13.90
> 30 dB HL	0.92	-14.15
> 35 dB HL	0.93	-13.90
> 40 dB HL	0.92	-14.15

Figure 6: ROC curves presenting test characteristics for antiphase GDTT SRT for detecting hearing threshold PTA – best ear (A) >25 dB HL, (B) >30 dB HL, (C) >35 dB HL, and (D) >40 dB HL.



Discussion

The GDTT was developed to provide a reliable hearing screening tool for adults living in Ghana. This test included two language recording sets: one in Asante-Twi and the other in Ghanaian English. The aim of the current study was to validate the performance of the GDTT for hearing screening among Ghanaian adults.

The study's results offer valuable insights into the relationships between hearing ability (PTA), self-reported hearing impairment (RHHI-S score), and diotic and antiphase SRTs, with specific reference to the Asante-Twi and Ghanaian English versions of the GDTT and RHHI-S scores. An audiogram-based classification of hearing levels revealed a spectrum of hearing thresholds in both ears.

GDTT: Asante-Twi group

Among the participants of the present study who indicated a preference to be tested with the Asante-Twi version of the GDTT (45), the majority had hearing within the normal range in both ears (51.1%, 23 participants) while 15.6% (7 participants) had bilateral symmetric sensorineural hearing loss, 20% (9 participants) had unilateral sensorineural hearing loss, and 13% (6 participants) had asymmetric sensorineural hearing loss.

For this group of participants, strong positive correlations were found between the best ear pure tone hearing threshold (average of the hearing threshold at 05, 1, 2, and 4 kHz) and the RHHI-S score ($r = 0.710$, $p < 0.001$), suggesting that higher hearing thresholds, indicating worse hearing, are associated with higher RHHI-S scores, reflecting a greater perceived hearing handicap. The correlation between the best ear PTA and the diotic SRT was even stronger ($r = 0.784$, $p < 0.001$), indicating that hearing is strongly associated with poorer performance on the diotic SRT test. The correlation between RHHI-S scores and SRT for the diotic condition showed a strong correlation ($r = 0.658$, $p < 0.001$), indicating that higher perceived hearing handicap correlated with poorer diotic SRT performance.

Overall, these results suggest a close relationship between hearing thresholds of the best ear, namely PTA and RHHI-S scores, as well as between hearing thresholds (the best ear PTA) and diotic SRTs, indicating that self-reported hearing impairment is closely associated with the classification of hearing loss as indicated by audiometric results and GDTT SRT. Conversely, the the correlation between RHHI-S scores and antiphase SRT stands at 0.784 ($p < 0.001$), showing consistent performance across both SRT, with higher perceived hearing handicap being associated with poorer performance. These findings underscore the connections between self-reported hearing impairment, audiometric assessments, and speech recognition thresholds in Asante-Twi speaker group.

GDTT: Ghanaian English group

Similarly, for Ghanaian English data, strong and significant correlations were observed between the hearing threshold (the best ear PTA) and RHHI-S score ($r = 0.825$, $p < 0.001$), as well as between the hearing threshold (the best ear PTA) and the diotic SRT ($r = 0.883$, $p < 0.001$). These results suggest a strong positive relationship between the hearing threshold (the best ear PTA) and the RHHI-S scores, implying that individuals classified with hearing loss via audiometric results may exhibit higher RHHI-S scores. The RHHI-S scores also correlated significantly with the diotic SRT ($r = 0.761$, $p < .001$), suggesting considerable overlap between these two classification methods in identifying hearing loss characteristics among Ghanaian English speaker groups. Thus, a higher perceived hearing handicap is associated with poor diotic SRT performance. Positive correlations between RHHI-S scores and hearing threshold (PTA) have been reported in previous studies (Cassarly et al., 2020; Folmer et al., 2017), indicating the validity of the Asante-Twi RHHI-S for screening for hearing impairment.

In the case of the antiphase SRT in Ghanaian English, it showed a positive correlation with RHHI-S scores ($r = 0.820$, $p < .001$), showing a very strong relationship where a higher perceived hearing handicap is associated with poorer antiphase SRT performance. This finding underscores the significance of the antiphase test in predicting hearing loss (De Sousa et al., 2022), especially unilateral loss, as self-reported hearing handicap measured by the RHHI-S score may be overlooked by a diotic test. A combined diotic and antiphase approach could offer further insights into different types of hearing loss, as suggested by De Sousa et al. (2022).

Connecting the results obtained in the study

Overall, the data indicates statistically significant correlations between the GDTT SRTs (Asante-Twi and Ghanaian English), audiometric pure-tone averaged thresholds, and RHHI-S scores, suggesting strong relationships between the various measures. However, the correlations tend to be slightly stronger in the Ghanaian English group compared to the Asante-Twi group. These findings show the potential utility of the GDTT as a good tool for hearing screening in Ghana, aligning with previous research findings (Folmer et al., 2017; Jansen et al., 2010; Potgieter et al., 2016; Smits et al., 2004; Watson et al., 2012). Clinically, this implies that the GDTT can serve as a screening tool for identifying hearing loss, particularly in settings where traditional audiometric equipment may be limited or inaccessible.

The AUC values suggested that the GDTT has strong discriminatory ability, making it a valuable tool for hearing screening in Ghana. The high sensitivity (AUC) of the GDTT across various cut-off points indicates its effectiveness in different hearing screening scenarios, allowing for the identification of individuals with the screened condition from those without it. For instance, for the Ghanaian English group, when the cut-off was set at 25 dB HL on the best ear, the diotic GDTT demonstrates high sensitivity with corresponding cut-off points of -9.7 dB. Similarly, at 30 dB and 35 dB HL, the sensitivity remains high, with corresponding cut-off points of -9.5 dB. This trend persists at 40 dB HL, with corresponding cut-off points of -9.3 dB (Table 5). These cut-off points were lower than those of Folmer et al. (2017) for the computer assisted DTT test (-8.5 dB). Similar findings were observed for the Asante-Twi group; for a cut-off set at 25 dB HL on the best ear (diotic), a sensitivity with a corresponding cut-off point of -9.7 dB was observed. At 30-, 35-, and 40-dB HL, the following cut-off points were observed; -9.7, -9.1, and -9.7 dB, respectively (Table 6). The GDTT therefore demonstrated strong discriminatory ability and high sensitivity in identifying hearing loss at various levels of severity. The GDTT's effectiveness in identifying hearing loss, particularly at lower decibel thresholds compared to previous methods, highlights its potential as a tool for hearing screening in resource-constraint settings in Ghana. This could enhance early identification and foster early intervention efforts for hearing loss.

Limitation of the study

One significant limitation of the study is the restricted sample, which was limited to individuals who learned Asante-Twi before the age of three and English at the age of six or later. This criterion excludes a considerable portion of the Ghanaian population whose linguistic experiences differ, such as individuals who were exposed to English earlier in life or who grew up in multilingual environments where multiple languages, including Asante-Twi, were acquired simultaneously.

As a result, the findings and validation outcomes of the GDTT may not be fully generalizable to all Ghanaians, particularly those who do not meet these specific linguistic criteria. This limitation highlights the need for further studies to validate the GDTT across a broader spectrum of linguistic profiles, including individuals with diverse language acquisition timelines and varying levels of proficiency in Asante-Twi and Ghanaian English. By doing so, the applicability and reliability of the test for the Ghanaian adult population can be better established.

The next step for future consideration is to explore the use of affordable, consumer-grade headphones. The current study relied on high-quality, expensive audiometric earphones, which could limit accessibility in low-resource settings. This presents a challenge in scaling up the use of the GDTT across various regions in Ghana, especially in rural and underserved areas. To facilitate broader implementation, it would be useful to validate the GDTT performance using more accessible and cost-effective consumer-grade headphones, ensuring its feasibility and effectiveness in diverse settings.

Conclusion

The results obtained in the present study confirm the Ghanaian Digit Triplet Test (GDTT) as a promising tool for hearing screening. Strong correlations were observed between the hearing thresholds and the SRT obtained in both the diotic and antiphase conditions. The ROC curves and the high sensitivity (AUC values) of the GDTT at various cut-off points for both diotic and antiphase conditions are an indication of the discriminatory ability of the tool for identifying hearing loss across both language groups, with particularly strong performance at the >35 dB HL threshold. The GDTT holds promise as a practical screening tool, especially in resource-constrained settings in Ghana.

In summary, this study sheds light on the relationships between hearing ability, self-reported hearing impairment as measured with the RHHI-S, and GDTT hearing screening outcomes among Asante-Twi and Ghanaian English speakers. Importantly, there were positive correlations between hearing loss classification and self-reported hearing impairment, as well as between hearing loss classification and diotic speech recognition thresholds (SRTs) and antiphase conditions in both language groups.

These findings highlight the importance of self-reported measures (Asante-Twi RHHI-S) in assessing hearing impairment, as they align closely with audiometric classifications. Moreover, the correlation observed between RHHI-S scores and antiphase SRTs suggests the potential utility of antiphase testing in predicting unilateral hearing loss, particularly in Ghanaian English speakers. The availability of two different tools – RHHI-S and GDTT – will allow the possibility to create a hearing screening protocol that can capture different aspects of hearing problems, i.e.: hearing handicap and hearing loss.

Acknowledgement

The authors would like to thank all participants for their participation and the staff of the Centre for Hearing and Speech Services, Winneba; the Hearing Assessment Centre, Korle Bu; and the Brobby Hearing Assessment Centre, Kumasi, for their willingness to allow the use of their facility and the support they provided.

Declaration of interest

The authors declare no potential conflicts of interest concerning this article's compilation, authorship, and/or publication. The authors are responsible for the content and writing of the article.

Reference

Akeroyd, M. A., Arlinger, S., Bentler, R. A., Boothroyd, A., Dillier, N., Dreschler, W. A., Gagné, J. P., Lutman, M., Wouters, J., Wong, L., & Kollmeier, B. (2015). International Collegium of Rehabilitative Audiology (ICRA) recommendations for the construction of multilingual speech tests. *International Journal of Audiology*, *54*, 17–22. https://doi.org/10.3109/14992027.2015.1030513

Akotey, S. C., Fynn, J. A., Danful, G. K., Offei, Y. N., & Amedofu, G. K. (2023). Development of audiology in Ghana: past, present, and future. *International Journal of Audiology*. https://doi.org/10.1080/14992027.2023.2263813

Akotey, S. C., Lagacé, J., Sauvé-Schenk, K., & Giguère, C. (2024). Translation and cross-cultural adaptation of the Revised Hearing Handicap Inventory screening tool into Asante-Twi. *J Otolaryng Head Neck Surg*, *10*, 1–6. ID: 246305444

Akotey, S. C., Lagacé, J., Giguère, C., & Sauvé-Schenk, K. (n.d., Submited: ID 24630544). Development and evaluation of the Ghanaian digit triplet test for hearing screening. *International Journal of Audiology*.

Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. *Ear and Hearing*, *41*(1), 95–105. https://doi.org/10.1097/AUD.0000000000000746

De Sousa, K. C., Smits, C., Moore, D. R., Myburgh, H. C., & Swanepoel, D. W. (2022). Diotic and Antiphasic Digits-in-noise Testing as a Hearing Screening and Triage Tool to Classify Type of Hearing Loss. *Ear and Hearing*, *43*(3), 1037–1048. https://doi.org/10.1097/AUD.0000000000001160

Folmer, R. L., Vachhani, J., McMillan, G. P., Watson, C., Kidd, G. R., & Patrick, F. M. (2017). Validation of a computer-administered version of the digit-in-boise test for hearing screening in the United States. *J Am Acad Audiol.*, *28*(2), 161–169. https://doi.org/10.3766/jaaa.16038

Giguère, C., Lagacé, J., Ellaham, N. N., Pichora-Fuller, M. K., Goy, H., Bégin, C., Alary, É., & Bowman, R. (2020). Development of the Canadian Digit Triplet Test in English and French. *The Journal of the Acoustical Society of America*, *147*(3), EL252–EL258. https://doi.org/10.1121/10.0000825

Jansen, S., Luts, H., Wagener, K. C., Frachet, B., & Wouters, J. (2010). The French digit triplet test: A hearing screening tool for speech intelligibility in noise. *International Journal of Audiology*, *49*(5), 378–387. https://doi.org/10.3109/14992020903431272

Mulwafu, W., Ensink, R., Kuper, H., & Fagan, J. (2017). Survey of ENT services in sub-Saharan Africa: Little progress between 2009 and 2015. *Global Health Action*, *10*(1). https://doi.org/10.1080/16549716.2017.1289736

Potgieter, J. M., Swanepoel, D. W., Myburgh, H. C., Hopper, T. C., & Smits, C. (2016). Development and validation of a smartphone-based digits-in-noise hearing test in South African English. *International Journal of Audiology*, *55*(7), 405–411. https://doi.org/10.3109/14992027.2016.1172269

Smits, C., Kapteyn, T. S., & Houtgast, T. (2004). Development and validation of an automatic speech-in-noise screening test by telephone. *International Journal of Audiology*, *43*(1), 15–28. https://doi.org/10.1080/14992020400050004

Smits, C., Kramer, S. E., & Houtgast, T. (2006). Speech reception thresholds in noise and self-reported hearing disability in a general adult population. *Ear and Hearing*, *27*(5), 538–549. https://doi.org/10.1097/01.aud.0000233917.72551.cf

Van den Borre, E., Denys, S., van Wieringen, A., & Wouters, J. (2021). The digit triplet test: a scoping review. In *International Journal of Audiology* (Vol. 60, Issue 12, pp. 946–963). Taylor and Francis Ltd. https://doi.org/10.1080/14992027.2021.1902579

Watson, C. S., Kidd, G. R., Miller, J. D., Smits, C., & Humes, L. E. (2012). Telephone screening tests for functionally impaired hearing: Current use in seven countries and development of a US version. *Journal of the American Academy of Audiology*, *23*(10), 757–767. https://doi.org/10.3766/jaaa.23.10.2

Zokoll, M. A., Hochmuth, S., Warzybok, A., Wagener, K. C., Buschermöhle, M., & Kollmeier, B. (2013). Speech-in-noise tests for multilingual hearing screening and diagnostics. *American Journal of Audiology*. https://doi.org/10.1044/1059-0889(2013/12-0061)

CHAPTER 6

General Discussion

The purpose of this thesis was to develop hearing screening material for the adult Ghanaian population. The ICF framework (World Health Organization, 2001) underpins the development of two types of screening material, namely a hearing screening questionnaire and a speech perception in noise screening test. This framework integrates various dimensions of health and disability, emphasizing the interaction between health conditions and contextual factors, which is important for creating an effective screening program (World Health Organization, 2001). The ICF framework promotes a shift from viewing health conditions as merely the "consequence of disease" to understanding them as "components of health" (World Health Organization, 2001). This perspective is important for recognizing the impacts of hearing loss on an individual's overall well-being, including physical, psychological, and social dimensions. This approach ensures that the screening material addresses not only the physiological aspects of hearing but also its broader implications on daily life and participation.

Specifically, the work carried out during this doctoral thesis includes the translation and adaptation of the Revised Hearing Handicap Inventory and Screening Tool (RHHI-S; Cassarly et al., 2020) into Asante-Twi, and the Digit Triplet Test (DTT: Smits et al., 2004) into Asante-Twi and Ghanaian English. The goal was to have hearing screening material that would be easily accessible for early identification of hearing loss among Ghanaian adults. This development addresses the gap in early identification of hearing loss due to the lack of appropriate local tools (Offei, 2017), ensuring broader reach, fostering early detection, and improving hearing health outcomes for Ghanaian adults.

The first paper (Chapter 2), titled *Development of Audiology in Ghana: Past, Present, and the Future* (Akotey et al., 2023), presented the historical perspective on the development of hearing health services in Ghana. This article describes the journey, from a period of quasi-absence of hearing healthcare services in Ghana to the emergence of a growing field. Despite the numerous challenges, including resource constraints, a scarcity of trained professionals, and limited public awareness, the paper also revealed significant progress, marked by the establishment of audiology departments in 20 facilities, educational programs in three universities, and research initiatives.

While this paper offered insights into the evolution of audiological services in Ghana, it also presents some limitations, mainly due to the scarcity of available information. The study relied on limited sources and anecdotal evidence, which could introduce gaps in understanding the historical journey. Furthermore, a more explicit discussion of policy implications and actionable recommendations would have provided a more in-depth perspective and helped identify the strategic priorities, such as capacity-building initiatives, advocacy efforts, etc. to catalyze the advancement of audiological services and improve hearing health outcomes in Ghana.

The translation and linguistic adaptation stages into Asante-Twi of the RHHI-S (Akotey et al., 2024) are presented in Chapter 3. Asante-Twi is Ghana's most widely spoken indigenous language (Appiah & Ardila, 2020; Ghana Statistical Service, 2021). A total of 87 participants, aged between 18 and 73 years, took part in the study. All participants were residents of Ghana and proficient in reading and speaking both Ghanaian English and Asante-Twi.

The study reveals that participants had no trouble understanding and completing the Asante-Twi version of the RHHI-S, suggesting that the efforts to linguistically adapt the instrument were successful. Additionally, the adapted instrument had a high test-retest reliability of the test items, with an ICC score of 0.946 for all the items, which indicates excellent consistency of the test results over time. The ICC score obtained with the Asante-Twi version of the RHHI-S is similar to the one reported for the original version (Cassarly et al., 2020; Newman et al., 1991). In terms of its linguistic aspect, these results suggest that the Asante-Twi version of the RHHI-S could be considered a valuable tool for screening hearing, after verification of its acceptance (i.e. verify if all the questionnaire items could be applied to the Ghanaian context).

Notwithstanding, the study could benefit from exploring the contextual factors that influence self-reported hearing perceptions among Asante-Twi speakers in interpreting RHHI-S scores accurately. Socioeconomic and environmental influences may shape individuals' subjective experiences of hearing difficulties (World Health Organization, 2001). The study could be improved by considering the social factors that influence how people perceive and report their hearing difficulties. By understanding these factors, the study can provide a more comprehensive interpretation of the RHHI-S scores, as hearing health issues might be perceived differently in certain localities compared to others.

The development stages of the adaptation of the Digit Triplet Test (DTT, Smits et al., 2004) in Ghanaian English and Asante-Twi (GDTT) are presented in Chapter 4. The Ghanaian version of the DTT includes three lists of 27 digits triplets recorded in Asante-Twi, as well as three lists of 27-digit triplets recorded in Ghanaian English. The Ghanaian spoken English has uniquely evolved by blending local linguistic and cultural influences into its vocabulary, pronunciation, and idiomatic expressions. For example, Ghanaian English exhibits spelling pronunciations influenced by the native languages (Adika, 2012).

The mean speech recognition thresholds (SRTs) obtained with the GDTT (-11.3 dB for Asante-Twi and -11.4 dB for Ghanaian English) using the diotic condition are similar to those of obtained with other language versions of the DTT (e.g.: Giguère et al., 2020; Jansen et al., 2010; Ozimek et al., 2009), as well as the psychometric parameters, including the slope (17.9%/dB for the Asante-Twi GDTT and 19.4%/dB for Ghanaian English) (Van den Borre et al., 2021; Zokoll et al., 2012, 2013). This similarity with the other language versions of the DTT not only promotes inclusivity in international research, for example, by facilitating cross-cultural comparisons and supporting global collaboration, but also ensures that language proficiency does not become a barrier to receiving necessary hearing services.

Overall, the results obtained demonstrate that the Asante-Twi DTT is linguistically appropriate for the Ghanaian population, including speakers of Asante-Twi and Ghanaian English. For instance, the results from the Asante-Twi version of the DTT showed no statistically significant differences between native and non-native speakers. This finding suggests that the test could be reliably used with speakers of Asante-Twi, regardless of whether it is their first or second language. Meanwhile, results from the Ghanaian English version of the DTT revealed statiscally significant differences in the partcipant scores based on the order of list presentation, particularly between the first and third lists, indicating a learning effect. This finding highlights the importance of sufficient training and practice before administering the Ghanaian English test to overcome the impact of the learning effect. Consequently, two sets of normative values are recommended for the Ghanaian English test to account for this variability. These findings collectively support the versatility and reliability of the GDTT in both Asante-Twi and Ghanaian English, making it an effective tool for hearing screening across diverse linguistic backgrounds in Ghana.

The GDTT is the first linguistic adaptation of the DTT to include polysyllabic digits (more than two syllables) instead of mono- and disyllabic digits in its constructions. All digits in Asante-Twi have three or more syllables except zero, which is disyllabic. As the results obtained with the

GDTT are similar to the other adaptations of the test, this suggests that polysyllabic stimuli could be used in screenings to capture different aspects of the auditory abilities.

Chapter 5 includes the details about the study that was conducted to investigate the validity of the GDTT. The validity was examined with the two language sets (Asante-Twi and Ghanaian English), as well as the two listening conditions (diotic and antiphase conditions). Relationships between hearing thresholds (PTA) and the SRT measured with the GDTT were examined, as well as the self-reported hearing impairment through the RHHI-S score and the GDTT, with a sample of 90 adult participants aged 18 to 50 years. All participants were fluent speakers of both Asante-Twi and Ghanaian English. They had learned Asante-Twi before the age of three years and Ghanaian English by age six.

Pure-tone audiometric measures revealed audiograms of different hearing degrees among the participants. Seventeen (37.8%) participants had a bilateral normal hearing, 12 (26.7%) presented a bilateral symmetric sensorineural hearing loss, 10 (22.2%) had asymmetric hearing loss, and 6 (13.3%) participants presented with asymmetric sensorineural hearing loss.

Prior to the testing, the participants were asked in which language – between Asante-Twi and Ghanaian English version – they preferred to be tested. The results were then organized in two groups, namely the Asante-Twi speaker group and the Ghanaian English speaker group. The analyses showed a strong correlation between SRTs measured with the GDTT in the diotic condition and RHHI-S scores in both groups, with a correlation coefficient of 0.658 ($p<0.001$) for the Asante-Twi speakers and 0.761 ($p<0.001$) for the Ghanaian English speakers. Additionally, the correlation between RHHI-S scores and antiphase SRT stands at 0.784 ($p<0.001$) for the Asante-Twi group. For the Ghanaian English, the correlation between antiphase SRT and diotic SRT was very strong, with a correlation of 0.941 ($p <0.001$). These findings demonstrate the robustness of the GDTT in assessing speech reception thresholds and its significant alignment with self-reported hearing handicap measures.

Strong correlations were observed between the best ear pure tone average and the GDTT diotic SRT for both language versions. For the Asante-Twi group, a correlation of 0.784 ($p < 0.001$) was observed, while the Ghanaian English group showed an even stronger correlation of 0.883 ($p < 0.001$). Similarly, for the correlation between the pure tone average and antiphase GDTT SRT, the Asante-Twi group showed a strong correlation of 0.809 ($p < 0.001$), and the Ghanaian English group exhibited the same high correlation of 0.883 ($p < 0.001$). These results underline the strong relationship between the GDTT speech reception thresholds and established audiometric measures, reinforcing the validity and reliability of the GDTT as an effective hearing screening tool across both language versions.

Future development and limitations of the study

Although not reported in the previous chapters, the relationship between the SRT measured with the GDTT and the score obtained on the RHHI-S for both groups of participants of the validation study was examined. Strong correlation coefficients were obtained for both groups: $r = 0.658$ for the Asante-Two group and $r = 0.761$ for the Ghanaian English group, suggesting that individuals with higher levels of hearing loss tend to report greater impairment via RHHI-S scores. This information provides some evidence that the RHHI-S could maybe use as a hearing screening tool on its own, provided prior validation. This could be an alternative for contexts in which access to computers or headsets is not possible.

Limitations of this study include the exclusive use of high-quality and expensive audiometric earphones (Radioear DD45 earphones, Eden Prairie, MN) during testing. To facilitate broader implementation, it would be useful to confirm the properties of the GDTT using more accessible and affordable consumer-grade earphones. This verification could aid in scaling up the use of the GDTT in various settings.

It will also be important to assess whether the GDTT remains effective and reliable when administered in rural communities lacking hearing clinics. In such settings, testing may be conducted by community nurses or other healthcare professionals who may not have training in audiometry. Evaluating the suitability and accuracy of the GDTT in these contexts is important for its widespread adoption and utility in community-based hearing healthcare initiatives.

Implementation the Ghanaian hearing screening program

Implementing a hearing screening program for adults in Ghana can significantly enhance public health by facilitating early detection of hearing loss. To successfully integrate this program into the healthcare system, several strategies need to be considered.

First, integrating the Ghanaian Digit Triplet Test (GDTT) into existing healthcare frameworks is essential. This test should be included in routine check-ups and health assessments at clinics, hospitals, and community health centers. Hearing screening services should be available in both urban and rural areas, utilizing mobile clinics and community health initiatives to reach underserved populations. Audiologists and healthcare providers should adopt and use the GDTT for initial screenings and follow-up assessments.

Secondly, the success of this program hinges on the acceptance and widespread utilization of the GDTT. In resource-limited settings like Ghana, beliefs and attitudes about hearing health significantly influence individuals' willingness to participate in screening or seek treatment for hearing loss. Therefore, it is essential to understand public perceptions of hearing loss, address stigma, and identify barriers to care. Public education campaigns can play a significant role in raising awareness about the importance of early detection and intervention.

Thirdly, government and policy support are vital. Policies should support funding for screening programs, training for providers, and access to hearing health services. Collaboration with government and non-governmental organizations to subsidize hearing assessments and intervention materials (e.g. hearing aids) could make these services affordable for all income levels. Such efforts will ensure its effective integration into the healthcare system and its acceptance by the Ghanaian population, ultimately enhancing hearing health outcomes across the country.

Conclusion

The development of the Ghanaian hearing screening material aligns with the World Health Organization's (2020) position that ear and hearing care should be part of universal health coverage. Moving forward, the findings of this thesis emphasized the importance of continued research to enhance the effectiveness and reach of hearing screening tools. Future research should focus on implementing and evaluating these tools in real-world settings, ensuring their effectiveness and scalability in diverse communities and healthcare contexts across Ghana. Ultimately, this study contributes to advancing audiological services and improving hearing health outcomes and quality of life for individuals with hearing conditions in Ghana.

Reference

Adika, G. S. K. (2012). English in Ghana: Growth, tensions, and trends. *International Journal of Language, Translation and Intercultural Communication*, *1*, 151. https://doi.org/10.12681/ijltic.17

Akotey, S. C., Fynn, J. A., Danful, G. K., Offei, Y. N., & Amedofu, G. K. (2023). Development of audiology in Ghana: past, present, and future. *International Journal of Audiology*. https://doi.org/10.1080/14992027.2023.2263813

Akotey, S. C., Lagacé, J., Sauvé-Schenk, K., & Giguère, C. (2024). Translation and cross-cultural adaptation of the Revised Hearing Handicap Inventory screening tool into Asante-Twi. *J Otolaryng Head Neck Surg*, *10*, 1–6.

Appiah, S. O., & Ardila, A. (2020). The question of school language in multilingual societies: The example of Ghana. *RUDN Journal of Psychology and Pedagogics*, *17*(2), 263–272. https://doi.org/10.22363/2313-1683-2020-17-2-263-272

Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The revised hearing handicap inventory and screening tool based on psychometric reevaluation of the hearing handicap inventories for the elderly and adults. *Ear and Hearing*, *41*(1), 95–105. https://doi.org/10.1097/AUD.0000000000000746

Ghana Statistical Service (GSS). (2021). *Ghana 2021 population and housing census - General report volume 3D: Literacy and education* (Vol. 3D). https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3D_Literacy and Education.pdf

Giguère, C., Lagacé, J., Ellaham, N. N., Pichora-Fuller, M. K., Goy, H., Bégin, C., Alary, É., & Bowman, R. (2020). Development of the Canadian digit triplet test in English and French. *The Journal of the Acoustical Society of America*, *147*(3), EL252–EL258. https://doi.org/10.1121/10.0000825

Jansen, S., Luts, H., Wagener, K. C., Frachet, B., & Wouters, J. (2010). The French digit triplet test: A hearing screening tool for speech intelligibility in noise. *International Journal of Audiology*, *49*(5), 378–387. https://doi.org/10.3109/14992020903431272

Newman, C. W., Weinstein, B. E., Jacobson, G. P., & Hug, G. A. (1991). Test-retest reliability of the hearing handicap inventory for adults. *Ear and Hearing*, *12*(5), 355–357. https://doi.org/10.1097/00003446-199110000-00009

Offei, Y. N. (2017). Audiology in Ghana. *Global Audiology*, 1–6.

Ozimek, E., Kutzner, D., Sek, A., & Wicher, A. (2009). Development and evaluation of Polish digit triplet test for auditory screening. *Speech Communication*, *51*(4), 307–316. https://doi.org/10.1016/j.specom.2008.09.007

Smits, C., Kapteyn, T. S., & Houtgast, T. (2004). Development and validation of an automatic speech-in-noise screening test by telephone. *International Journal of Audiology*, *43*(1), 15–28. https://doi.org/10.1080/14992020400050004

Van den Borre, E., Denys, S., van Wieringen, A., & Wouters, J. (2021). The digit triplet test: A scoping review. In *International Journal of Audiology* (Vol. 60, Issue 12, pp. 946–963). Taylor and Francis Ltd. https://doi.org/10.1080/14992027.2021.1902579

World Health Organization. (2001). *International classification of functioning, disability and health: ICF*.

Zokoll, M. A., Hochmuth, S., Warzybok, A., Wagener, K. C., Buschermöhle, M., & Kollmeier, B. (2013). Speech-in-noise tests for multilingual hearing screening and diagnostics. *American Journal of Audiology*. https://doi.org/10.1044/1059-0889(2013/12-0061)

Zokoll, M. A., Wagener, K. C., Brand, T., Buschermöhle, M., & Kollmeier, B. (2012). Internationally comparable screening tests for listening in noise in several European languages: The German digit triplet test as an optimization prototype. *International Journal of Audiology*, *51*(9), 697–707. https://doi.org/10.3109/14992027.2012.690078

APPENDIX I

Consent for Participation in Survey.

Phase 1 – Translation and adaptation of the Revised Hearing Handicap Inventory and Screening questionnaire

1. **<u>Title of the research project</u>**
   Development of a hearing screening protocol for adult population in Ghana
2. **<u>Name of the researchers</u>**

Principal Investigator	Supervisor	Co-investigator
Sesi Collins Akotey PhD Candidate School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa Email: Phone:	**Josée Lagacé (PhD)** Associate Professor, Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:	**Christian Giguère (PhD)** Full Professor Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:

3. **<u>Invitation to take part in research study</u>**
   I am invited to participate in the above-mentioned research study conducted by Sesi Collins Akotey. The principal investigator is responsible for data collection. This is a doctoral thesis research project.

4. **<u>Purpose of the study</u>**
   The purpose of the study is to explore and develop a hearing screening protocol for the adult Ghanaian population who are speaker of Asante-Twi.

5. **<u>Participation</u>**
   My participation in the study will consist of filling in an online questionnaire (the adapted version of the Revised Hearing Handicap Inventory and Screening questionnaire in Asante-Twi). If I consent to participate, I will have access to the questionnaire. I will fill in the questionnaire for myself. Filling in this questionnaire online will take approximately 15 minutes. In about 1-2 weeks, I will receive an email asking me to fill in this same questionnaire a second time. This process is necessary to validate the questionnaire. If I do not consent to participate, I will receive a thank you note.
   After having received the initial invitation to fill in the questionnaire, I will receive one reminder email if I have not yet completed the questionnaire. I will also receive one

reminder email after receiving the invitation email to fill in the questionnaire for the second time.

6. **Risks**
I understand that in the questionnaire there are questions that may relate to my personal listening experience in various situations. I might experience emotional discomfort while answering the questions. I have received assurance from the researcher that everything is done to minimize my discomfort. I understand that I can choose to stop the activity, or I can choose to not answer some questions.

7. **Benefits**
My participation in this study will help the researcher develop a final version of this questionnaire in the Asante-Twi language. The questionnaire could then be used in several hearing assessment facilities and improve the services offered to patients with hearing difficulties.

8. **Confidentiality and Privacy**
The information I will share with the researcher will remain strictly confidential and will only be used for the analysis and the preparation of a summary report. I will not give my first or last names when filling in the questionnaire. My IP address will be saved by the SurveyMonkey online platform used for the online questionnaire. I will give the research team my email address so that they can send me the questionnaire. My email address will also be used to send me the questionnaire a second time. My email address will be protected in the following ways: my address will be saved on the SurveyMonkey platform which can only be accessed by the research team. As well, my email address will not be used during data analysis because the team will use my participation number instead.
In order to minimize the risk of security breaches and to help ensure my confidentiality, it is recommended that I use standard safety measures, such as signing out of my account, closing my browser, and locking my device when I am no longer using it/when I have completed the study.

9. **Conservation of Data**
The researcher will keep the consent form where I provide my consent and email address. My email address and my questionnaire answers will be stored on SurveyMonkey and will be accessible only to the research team using a password. The questionnaires are completed on the SurveyMonkey platform, and my data will be securely saved on their Canadian servers.
Any publications will not contain any of my personal information (for example, my email address). All data will be kept for a period of five years after the end of the project and will be destroyed afterwards. Electronic data will be deleted.

10. **Compensation**
There is no compensation for participating in the study.

11. <u>Voluntary Participation</u>

My participation in this study is voluntary and I am free to withdraw at any time, and/or refuse to answer any of the questions, without any negative consequences.

12. <u>Agreement</u>

I agree to participate in this study conducted by Sesi Collins Akotey from the School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa.

If I have any questions about the study, I may contact the researcher or his supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via (ethics@uottawa.ca) or telephone (613-562-5387).

I am invited to print/save a copy of this consent form for my records.

Agreement or refusal

□ I agree to complete the survey and I agree with the study conditions
□ I refuse to complete the survey

Agreement or refusal to participate in the second part

□ I agree to participate in the second part of this study
□ I refuse to participate in the second part of this study

Sharing of email address

□ I agree to share my email address to the researcher, so that I can receive the web link for the initial questionnaire, the invitation to complete the questionnaire a second time, and to receive reminders.

□ I do not agree to share my email address to the researcher, so that I cannot receive the web link for the initial questionnaire, the invitation to complete the questionnaire a second time, and to receive reminders.

APPENDIX II

Information and Consent Form.

Phase I - Development of an Asante-Twi version of the Digit Triplet Test

1. **Title of the research project**

   Development of a hearing screening protocol for adult population in Ghana

2. **Name of the researchers**

Principal Investigator	Supervisor	Co-investigator
Sesi Collins Akotey PhD Candidate School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa Email: Phone:	**Josée Lagacé (PhD)** Associate Professor, Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:	**Christian Giguère (PhD)** Full Professor Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:

3. **Invitation to take part in research study**

   I am invited to participate in the above-mentioned research study conducted by Sesi Collins Akotey. This is a doctoral thesis research project.

4. **Purpose of the study**

   The purpose of the study is to explore and develop a hearing screening protocol for the adult Ghanaian population, who are speaker of Asante-Twi.

5. **Participation**

   My participation in this part of the study (Phase II) consists of one session of hearing measures conducted at the Hearing Research Laboratory, located at the Roger Guindon Hall. This session will include the following measures:

   Hearing screening

   i. *Questionnaire on general development:* I will be asked to fill out a questionnaire regarding past or current problems involving language development, attention, hearing, and overall general development. This information will determine if I meet the criteria for inclusion in the research study (i.e.: no antecedent of hearing problem).

ii. *Questionnaire on language experience:* I will be asked to fill out a questionnaire on linguistic experience at home, school, work and during leisure activities. The answers will help determine if my linguistic experience can affect performance on speech-in-noise measures.

iii. *Pure tone hearing screening.* Using an otoscope, the auditory canals will be examined to ensure that nothing could prevent me from taking part in the study (for example earwax blockage or active ear infection). Then, I will be asked to listen to soft sounds presented through headphones and to press a button each time I hear a sound.

The information gathered with these measures will determine if I meet the criteria for inclusion in the research study (e.g: no hearing problem) and ensure I have a sufficient linguistic experience in Asante-Twi, which is the language used in the speech-in-noise test. Duration: 45 minutes.

<u>Speech-in-noise test</u>
I will be asked to repeat series of digits presented through headphones at different levels, not exceeding 80 dBA. I will repeat the series of digits on a keypad, or a touch screen. The digit series, which are in Asante-Twi, will be presented simultaneously with background noise. I will be encouraged to guess the digits when unsure of what was heard. Duration: 45 minutes.

Results of the hearing screening will be explained. However, results obtained with the digits in noise test will not be communicated to me since the data analysis will occur at a later time and will be performed on pooled data from all participants.

6. <u>Risks</u>
I understand that I will partake in different hearing measures tests and might experience emotional discomfort while answering the questions or doing the pure tone hearing screening test for example. I have received assurance from the researcher that everything is done to minimize my discomfort. I understand that I can choose to stop the activity, or I can choose to not answer some questions.

7. <u>Benefits</u>
My participation in this study will provide me a free hearing evaluation and have an opportunity to discuss my results. Additionally, my participation will facilitate the process of developing a hearing test for my society and contribute to the advancement of knowledge.

8. <u>Confidentiality and Privacy</u>
The information I will share with the researcher will remain strictly confidential and will only be used for the analysis and the preparation of a summary report. I will not give my first or last names when filling in the questionnaire. I will give the research team my email address so that I can be contacted when needed. My email address will be protected and saved with a password

accessed only by the research team. As well, my email address will not be used during data analysis because the team will use my participation number instead.

9. <u>Conservation of Data</u>

The researcher will keep the consent form where I provide my consent, email address and demographics. I will have the option to keep a copy of this consent form for my records.
Any publications will not contain any of my personal information (for example, my email address). All data will be kept for a period of five years after the end of the project and will be destroyed afterwards. Electronic data will be deleted. The research will maintain the confidentiality of the research records or data, and all data will be destroyed after the completion of the study (5 years).

10. <u>Compensation</u>

There is no compensation for participating in the study.

11. <u>Voluntary Participation</u>

My participation in this study is voluntary and I am free to withdraw at any time, and/or refuse to answer any of the questions, without any negative consequences.

12. **<u>Agreement</u>**

I agree to participate in this study conducted by Sesi Collins Akotey from the School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa.

If I have any questions about the study, I may contact the researcher or his supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via (ethics@uottawa.ca).

I am invited to print/save a copy of this consent form for my records.

Acceptance: By signing my name below, I agree to participate in this research study.

Participant's name: ________________ ________________________ Date:________________

Participant's email/Telephone number: ________________________ Date:________________

Participant's signature: ____ Date:________________

Researcher's signature: ____ Date:________________

APPENDIX III

Information and Consent Form.

Phase III – Validation of the hearing screening protocol

1. **Title of the research project**
   Development of a hearing screening protocol for adult population in Ghana

2. **Name of the researchers**

Principal Investigator	Supervisor	Co-investigator
Sesi Collins Akotey PhD Candidate School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa Email: Phone:	**Josée Lagacé (PhD)** Associate Professor, Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:	**Christian Giguère (PhD)** Full Professor Audiology and Speech-Language Pathology Program School of Rehabilitation Sciences Faculty of Health Sciences University of Ottawa 451, Smyth Road Ottawa, ON K1H 8M5 Email: Phone:

3. **Invitation to take part in research study**
   I am invited to participate in the above-mentioned research study conducted by Sesi Collins Akotey. This is a doctoral thesis research project.

4. **Purpose of the study**
   The purpose of the study is to explore and develop a hearing screening protocol for the adult Ghanaian population, who are speaker of Asante-Twi.

5. **Participation**
   My participation in this part of the study (Phase III) will include the following measures:

   i. Questionnaire – adapted version of RHHI-S in Asante-Twi

   I will be asked to fill out a questionnaire regarding my hearing abilities. This information, as well as my results on the hearing screening test, will be put together for analysis. Duration:15 minutes.

   ii. Audiological screening – Pure tone audiometry

   Using an otoscope, my auditory canals will be examined to ensure that nothing could prevent me from taking part in the study (for example earwax blockage or active ear infection). Then, I will be asked to listen to soft sounds presented through headphones and to press a button each time I hear a sound. Duration: 45 minutes.

   iii. Experimental measures – A-TDTT

I will be asked to listen to and repeat digits presented through headphones, at different levels, not exceeding 80 dBA. The lists of the digits will be presented with or without the presence of background noise and I will repeat the heard sequences (3 digits at a time) on a keypad, or touch screen. I am to do my best to repeat the digit sequences and will be asked to guess when unsure of the response. In the case when the digits triplets will be presented simultaneously with a background noise, the level of that noise will never be exceeding 65 dBA. Duration: 15 minutes.

I will receive an invitation to re-do the same hearing measures two weeks after, but I am not obligated to participate in this second set of hearing evaluations. If I accept to participate to this second session of measures, it will be scheduled at a time that is convenient for me. The duration will be the same.

Results of the hearing screening (i and ii) will be explained. However, results obtained with the digits in noise test will not be communicated to me since the data analysis will occur at a later time and will be performed on pooled data from all participants.

6. **<u>Risks</u>**
   I understand that I will partake in different hearing measures and might experience emotional discomfort while answering the questions or doing the pure tone hearing screening test for example. I have received assurance from the researcher that everything is done to minimize my discomfort. I understand that I can choose to stop the activity, or I can choose to not answer some questions.

7. **<u>Benefits</u>**
   My participation in this study will provide me a free hearing screening and have an opportunity to discuss my hearing test results. Additionally, my participation will facilitate the process of developing a hearing test for my society and contribute to the advancement of knowledge.

8. **<u>Confidentiality and Privacy</u>**
   The information I will share with the researcher will remain strictly confidential and will only be used for the analysis and the preparation of a summary report. I will not give my first or last names when filling in the questionnaire. My IP address will be saved, and email address will be protected, password saved and will not be used during data analysis because the team will use my participation number instead.

9. **<u>Conservation of Data</u>**
   The researcher will keep the consent form where I provide my consent, email address and demographics. I will have the option to keep a copy of this consent form for my records.

   Any publications will not contain any of my personal information (for example, my email address). All data will be kept for a period of five years after the end of the project and will be destroyed afterwards. Electronic data will be deleted. The research will maintain the confidentiality of the research records or data, and all data will be destroyed after the completion of the study (5 years).

10. Compensation
There is no compensation for participating in the study.

11. Voluntary Participation
My participation in this study is voluntary and I am free to withdraw at any time, and/or refuse to answer any of the questions, without any negative consequences.

12. **Agreement**
I agree to participate in this study conducted by Sesi Collins Akotey from the School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa.
If I have any questions about the study, I may contact the researcher or his supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via (ethics@uottawa.ca).

Agreement or refusal

□ I agree to participate in the first part of the study and its conditions
□ I refuse to participate

Agreement or refusal to participate in the second part

□ I agree to participate in the second part of this study
□ I refuse to participate in the second part of this study

Sharing of email address

□ I agree to share my email address to the researcher, so he contact me for the second part of the study.
□ I do not agree to share my email address to the researcher, for him to contact me for the second part of the study.

I am invited to print/save a copy of this consent form for my records.

Participant's name: ________________ ________________________ Date:________________

Participant's email/Telephone number: ________________________ Date:________________

Participant's signature: ____ Date:________________

Researcher's signature: ____ Date:________________

APPENDIX IV

License to Adapt and Translate RHHI-S.

WOLTERS KLUWER HEALTH, INC. LICENSE

TERMS AND CONDITIONS
Mar 01, 2021

This Agreement between Mr. Sesi Akotey ("You") and Wolters Kluwer Health, Inc. ("Wolters Kluwer Health, Inc.") consists of your license details and the terms and conditions provided by Wolters Kluwer Health, Inc. and Copyright Clearance Center.

License Number	5020450660660
License date	Mar 01, 2021
Licensed Content Publisher	Wolters Kluwer Health, Inc.
Licensed Content Publication	Ear and Hearing
Licensed Content Title	The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults
Licensed Content Author	Christy Cassarly, Lois J. Matthews, Annie N. Simpson, et al
Licensed Content Date	May 20, 2019
Licensed Content Volume	41
Licensed Content Issue	1
Type of Use	Dissertation/Thesis
Requestor type	University/College
Sponsorship	No Sponsorship
Format	Print and electronic
Will this be posted online?	Yes, on a secure website
Portion	Figures/tables/illustrations
Number of figures/tables/illustrations	1
Author of this Wolters Kluwer article	No
Will you be translating?	Yes
Number of languages	1
Intend to modify/change the content	No
Title	Development of a hearing screening protocol for adult population in Ghana
Institution name	School of Rehabilitation Sciences, University of Ottawa, Canada

Expected presentation date	Jul 2023
Order reference number	_00D30oeGz._5004Q2Cd74N:ref
Portions	Table 7 on page 103
Specific Languages	Asante Twi
Requestor Location	Mr. Sesi Akotey 1381 Heron Road K1V 6A6 Ottawa, ON K1V 6A6 Canada Attn: School of Rehabilitation Sciences, University of Ottawa, Canda
Publisher Tax ID	13-2932696
Total	0.00 CAD

Terms and Conditions

Wolters Kluwer Health Inc. Terms and Conditions

1. **Duration of License:** Permission is granted for a one time use only. Rights herein do not apply to future reproductions, editions, revisions, or other derivative works. This permission shall be effective as of the date of execution by the parties for the maximum period of 12 months and should be renewed after the term expires.
    i. When content is to be republished in a book or journal the validity of this agreement should be the life of the book edition or journal issue.

    ii. When content is licensed for use on a website, internet, intranet, or any publicly accessible site (not including a journal or book), you agree to remove the material from such site after 12 months, or request to renew your permission license
2. **Credit Line:** A credit line must be prominently placed and include: For book content: the author(s), title of book, edition, copyright holder, year of publication; For journal content: the author(s), titles of article, title of journal, volume number, issue number, inclusive pages and website URL to the journal page; If a journal is published by a learned society the credit line must include the details of that society.
3. **Warranties:** The requestor warrants that the material shall not be used in any manner which may be considered derogatory to the title, content, authors of the material, or to Wolters Kluwer Health, Inc.
4. **Indemnity:** You hereby indemnify and hold harmless Wolters Kluwer Health, Inc. and its respective officers, directors, employees and agents, from and against any and all claims, costs, proceeding or demands arising out of your unauthorized use of the Licensed Material
5. **Geographical Scope:** Permission granted is non-exclusive and is valid throughout the world in the English language and the languages specified in the license.

6. **Copy of Content:** Wolters Kluwer Health, Inc. cannot supply the requestor with the original artwork, high-resolution images, electronic files or a clean copy of content.
7. **Validity:** Permission is valid if the borrowed material is original to a Wolters Kluwer Health, Inc. imprint (J.B Lippincott, Lippincott-Raven Publishers, Williams & Wilkins, Lea & Febiger, Harwal, Rapid Science, Little Brown & Company, Harper & Row Medical, American Journal of Nursing Co, and Urban & Schwarzenberg English Language, Raven Press, Paul Hoeber, Springhouse, Ovid), and the Anatomical Chart Company
8. **Third Party Material:** This permission does not apply to content that is credited to publications other than Wolters Kluwer Health, Inc. or its Societies. For images credited to non-Wolters Kluwer Health, Inc. books or journals, you must obtain permission from the source referenced in the figure or table legend or credit line before making any use of the image(s), table(s) or other content.
9. **Adaptations:** Adaptations are protected by copyright. For images that have been adapted, permission must be sought from the rightsholder of the original material and the rightsholder of the adapted material.
10. **Modifications:** Wolters Kluwer Health, Inc. material is not permitted to be modified or adapted without written approval from Wolters Kluwer Health, Inc. with the exception of text size or color. The adaptation should be credited as follows: Adapted with permission from Wolters Kluwer Health, Inc.: [the author(s), title of book, edition, copyright holder, year of publication] or [the author(s), titles of article, title of journal, volume number, issue number, inclusive pages and website URL to the journal page].
11. **Full Text Articles:** Republication of full articles in English is prohibited.
12. **Branding and Marketing:** No drug name, trade name, drug logo, or trade logo can be included on the same page as material borrowed from *Diseases of the Colon & Rectum, Plastic Reconstructive Surgery, Obstetrics & Gynecology (The Green Journal), Critical Care Medicine, Pediatric Critical Care Medicine, the American Heart Association publications and the American Academy of Neurology publications.*
13. **Open Access:** Unless you are publishing content under the same Creative Commons license, the following statement must be added when reprinting material in Open Access journals: "The Creative Commons license does not apply to this content. Use of the material in any format is prohibited without written permission from the publisher, Wolters Kluwer Health, Inc. Please contact permissions@lww.com for further information."
14. **Translations:** The following disclaimer must appear on all translated copies: Wolters Kluwer Health, Inc. and its Societies take no responsibility for the accuracy of the translation from the published English original and are not liable for any errors which may occur.
15. **Published Ahead of Print (PAP):** Articles in the PAP stage of publication can be cited using the online publication date and the unique DOI number.

i. Disclaimer: Articles appearing in the PAP section have been peer-reviewed and accepted for publication in the relevant journal and posted online before print publication. Articles appearing as PAP may contain statements, opinions, and information that have errors in facts, figures, or interpretation. Any final changes in manuscripts will be made at the time of print publication and will be reflected in the final electronic version of the issue. Accordingly, Wolters Kluwer Health, Inc., the editors, authors and their respective employees are not responsible or liable for the use of any such inaccurate or misleading data, opinion or information contained in the articles in this section.

16. **Termination of Contract:** Wolters Kluwer Health, Inc. must be notified within 90 days of the original license date if you opt not to use the requested material.
17. **Waived Permission Fee:** Permission fees that have been waived are not subject to future waivers, including similar requests or renewing a license.
18. **Contingent on payment:** You may exercise these rights licensed immediately upon issuance of the license, however until full payment is received either by the publisher or our authorized vendor, this license is not valid. If full payment is not received on a timely basis, then any license preliminarily granted shall be deemed automatically revoked and shall be void as if never granted. Further, in the event that you breach any of these terms and conditions or any of Wolters Kluwer Health, Inc.'s other billing and payment terms and conditions, the license is automatically revoked and shall be void as if never granted. Use of materials as described in a revoked license, as well as any use of the materials beyond the scope of an unrevoked license, may constitute copyright infringement and publisher reserves the right to take any and all action to protect its copyright in the materials.
19. **STM Signatories Only:** Any permission granted for a particular edition will apply to subsequent editions and for editions in other languages, provided such editions are for the work as a whole in situ and do not involve the separate exploitation of the permitted illustrations or excerpts. Please view: STM Permissions Guidelines
20. **Warranties and Obligations:** LICENSOR further represents and warrants that, to the best of its knowledge and belief, LICENSEE's contemplated use of the Content as represented to LICENSOR does not infringe any valid rights to any third party.
21. **Breach:** If LICENSEE fails to comply with any provisions of this agreement, LICENSOR may serve written notice of breach of LICENSEE and, unless such breach is fully cured within fifteen (15) days from the receipt of notice by LICENSEE, LICENSOR may thereupon, at its option, serve notice of cancellation on LICENSEE, whereupon this Agreement shall immediately terminate.
22. **Assignment:** License conveyed hereunder by the LICENSOR shall not be assigned or granted in any manner conveyed to any third party by the LICENSEE without the consent in writing to the LICENSOR.
23. **Governing Law:** The laws of The State of New York shall govern interpretation of this Agreement and all rights and liabilities arising hereunder.

24. **Unlawful:** If any provision of this Agreement shall be found unlawful or otherwise legally unenforceable, all other conditions and provisions of this Agreement shall remain in full force and effect.

For Copyright Clearance Center / RightsLink Only:

1. **Service Description for Content Services:** Subject to these terms of use, any terms set forth on the particular order, and payment of the applicable fee, you may make the following uses of the ordered materials:

    i. **Content Rental:** You may access and view a single electronic copy of the materials ordered for the time period designated at the time the order is placed. Access to the materials will be provided through a dedicated content viewer or other portal, and access will be discontinued upon expiration of the designated time period. An order for Content Rental does not include any rights to print, download, save, create additional copies, to distribute or to reuse in any way the full text or parts of the materials.

    ii. **Content Purchase:** You may access and download a single electronic copy of the materials ordered. Copies will be provided by email or by such other means as publisher may make available from time to time. An order for Content Purchase does not include any rights to create additional copies or to distribute copies of the materials

APPENDIX V

Information and Consent Form.

Phase II - Development of an Asante-Twi version of the Digit Triplet Test

13. <u>Title of the research project</u>

Development of a hearing screening protocol for adult population in Ghana

14. <u>Name of the researchers</u>

Principal Investigator	Supervisor	Co-investigator
Sesi Collins Akotey	**Josée Lagacé (PhD)**	**Christian Giguère (PhD)**
PhD Candidate	Associate Professor,	Full Professor
School of Rehabilitation Sciences	Audiology and Speech-Language Pathology Program	Audiology and Speech-Language Pathology Program
Faculty of Health Sciences	School of Rehabilitation Sciences	School of Rehabilitation Sciences
University of Ottawa	Faculty of Health Sciences	Faculty of Health Sciences
	University of Ottawa	University of Ottawa
	451, Smyth Road	451, Smyth Road
Email:	Ottawa, ON K1H 8M5	Ottawa, ON K1H 8M5
Phone:	Email:	Email:
	Phone:	Phone:

15. <u>Invitation to take part in research study</u>

I am invited to participate in the above-mentioned research study conducted by Sesi Collins Akotey. This is a doctoral thesis research project.

16. **Purpose of the study**

The purpose of the study is to explore and develop a hearing screening protocol for the adult Ghanaian population, who are speaker of Asante-Twi.

17. <u>Participation</u>

My participation in this part of the study (Phase II) consists of one session of hearing measures conducted at the Hearing Research Laboratory, located at the Centre for Hearing and Speech Sercies, University of Education, Winneba, Ghana. This session will include the following measures:

<u>Hearing screening</u>

i. *Questionnaire on general development:* I will be asked to fill out a questionnaire regarding past or current problems involving language development, attention, hearing, and overall general development. This information will determine if I meet the criteria for inclusion in the research study (i.e.: no antecedent of hearing problem).

ii. *Questionnaire on language experience:* I will be asked to fill out a questionnaire on linguistic experience at home, school, work and during leisure activities. The answers will help determine if my linguistic experience can affect performance on speech-in-noise measures.

iv. *Pure tone hearing screening.* Using an otoscope, the auditory canals will be examined to ensure that nothing could prevent me from taking part in the study (for example earwax blockage or active ear infection). Then, I will be asked to listen to soft sounds presented through headphones and to press a button each time I hear a sound.

The information gathered with these measures will determine if I meet the criteria for inclusion in the research study (e.g: no hearing problem) and ensure I have a sufficient linguistic experience in Asante-Twi, which is the language used in the speech-in-noise test. Duration: 45 minutes.

Speech-in-noise test

I will be asked to repeat series of digits presented through headphones at different levels, not exceeding 80 dBA. I will repeat the series of digits on a keypad, or a touch screen. The digit series, which are in Asante-Twi, will be presented simultaneously with background noise. I will be encouraged to guess the digits when unsure of what was heard. Duration: 45 minutes.

Results of the hearing screening will be explained. However, results obtained with the digits in noise test will not be communicated to me since the data analysis will occur at a later time and will be performed on pooled data from all participants.

18. Risks

I understand that I will partake in different hearing measures tests and might experience emotional discomfort while answering the questions or doing the pure tone hearing screening test for example. I have received assurance from the researcher that everything is done to minimize my discomfort. I understand that I can choose to stop the activity, or I can choose to not answer some questions.

19. Benefits

My participation in this study will provide me a free hearing evaluation and have an opportunity to discuss my results. Additionally, my participation will facilitate the process of developing a hearing test for my society and contribute to the advancement of knowledge.

20. Confidentiality and Privacy

The information I will share with the researcher will remain strictly confidential and will only be used for the analysis and the preparation of a summary report. I will not give my first or last names when filling in the questionnaire. I will give the research team my email address so that I can be contacted when needed. My email address will be protected and saved with a password accessed only by the research team. As well, my email address will not be used during data analysis because the team will use my participation number instead.

21. Conservation of Data

The researcher will keep the consent form where I provide my consent, email address and demographics. I will have the option to keep a copy of this consent form for my records.
Any publications will not contain any of my personal information (for example, my email address). All data will be kept for a period of five years after the end of the project and will be destroyed afterwards. Electronic data will be deleted. The research will maintain the confidentiality of the research records or data, and all data will be destroyed after the completion of the study (5 years).

22. Compensation

There is no compensation for participating in the study.

23. Voluntary Participation

My participation in this study is voluntary and I am free to withdraw at any time, and/or refuse to answer any of the questions, without any negative consequences.

24. **Agreement**

I agree to participate in this study conducted by Sesi Collins Akotey from the School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa.

If I have any questions about the study, I may contact the researcher or his supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via (ethics@uottawa.ca).

I am invited to print/save a copy of this consent form for my records.

Acceptance: By signing my name below, I agree to participate in this research study.

Participant's name: ________________ ________________________ Date:________________

Participant's email/Telephone number: ________________________ Date:________________

Participant's signature: ____ Date:________________

Researcher's signature: ____ Date:________________

APPENDIX VI

Ethics Approval.

14/09/2021

Université d'Ottawa — Bureau d'éthique et d'intégrité de la recherche

University of Ottawa — Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE I CERTIFICATE OF ETHICS APPROVAL

Numéro du dossier / Ethics File Number	H-05-21-5674
Titre du projet / Project Title	DEVELOPMENT OF A HEARING SCREENING PROTOCOL FOR ADULT POPULATION IN GHANA
Type de projet / Project Type	Thèse de doctorat / Doctoral thesis
Statut du projet / Project Status	Approuvé / Approved
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	14/09/2021
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	13/09/2022

Équipe de recherche / Research Team

Chercheur / Researcher	Affiliation	Role
Sesi AKOTEY	École des sciences de la réadaptation / School of Rehabilitation Sciences	Chercheur Principal / Principal Investigator
Josée LAGACÉ	École des sciences de la réadaptation / School of Rehabilitation Sciences	Superviseur / Supervisor
Christian GIGUÈRE	École des sciences de la réadaptation / School of Rehabilitation Sciences	Co-chercheur / Co-investigator

Conditions spéciales ou commentaires / Special conditions or comments

550, rue Cumberland, pièce 154 550 Cumberland Street, Room 154
Ottawa (Ontario) K1N 6N5 Canada Ottawa, Ontario K1N 6N5 Canada

613-562-5387 • 613-562-5338 • ethique@uOttawa.ca / ethics@uOttawa.ca
www.recherche.uottawa.ca/deontologie | www.recherche.uottawa.ca/ethics

APPENDIX VII

Final version – Asante-Twi RHHI-S.

NHWEHWZMU A ZFA OTIE HO AKWANSIDIE NSAKRAMU - NYAREWA NHWEHWƐMU

Deɛ Wɔrehwehwɛ N'asom no Nɔma: ______________________ Ɛda:_______________ - - - - -

AKWANKYERƐ: Nkyekyɛmu yi botaeɛ ne sɛ yɛbɛhunu x x w'aso a z z bɛtumi de abrɛ wo. ***Mesrɛ wo, yi DAABI, ƐTƆ DA BI A, anaa AANE ma asɛmmisa biara. Nnya asɛmmisa biara nto hɔ sɛ wosi wo tebea bi ho kwan ɛnam sɛ wowɔ otie mu haw nti. Sɛ wode deɛ wɔde tie asɛm no hyɛ w'aso a, mesrɛ wo yi ano sɛnea wote no no berɛ a adeɛ a wɔde tie biara nni hɔ.***

Nɔma	Asɛmmisa	Daabi	Ɛtɔ da bi a	Aane
1	Sɛ woretie TV anaa radio a, ɔhaw a wowɔ no wɔ otie mu no ma no yɛ den ma wo anaa?			
2	Sɛ wokɔ apontoɔ bi ase a, ɔhaw a wowɔ wɔ otie mu no ma no yɛ den ma wo anaa?			
3	So otie mu haw ma w'abam bu berɛ a wo ne w'abusuafoɔ retwetwe nkɔmmɔ anaa?			
4	Otie mu haw ma wote nka sɛ wɔapo wo berɛ a wo ne nnipakuo bi wɔ hɔ anaa?			
5	Berɛ a worekɔsra wo nnamfo, w'abusua, anaa wo fipamfoɔ no, ɔhaw a wowɔ wɔ otie mu ma no yɛ den ma wo anaa?			
6	Otie mu haw ma wonya atenka bi sɛ wotx sini anaa?			
7	Wote nka sɛ ɔhaw biara a wowɔ no wɔ otie ho no ha w'ankasa anaa wo ne nnipakuo bi abrabɔ anaa?			
8	Ɔhaw a wowɔ no wɔ otie mu no mma w'ani nnye berɛ a wo ne wo nnamfonom redi nkɔmmɔ anaa?			
9	Otie mu haw ma wogyina so po nkurɔfokuo anaa?			
10	Otie mu haw no mma wo kwan mma wonsrasra wo nnamfo, w'abusuafoɔ, anaa w'afipamfoɔ sɛdeɛ anka wopɛ sɛ woyɛ no anaa?			

Adapted from Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. Ear & Hearing, 41 (1). 95-105.

APPENDIX VIII

Forward Translation of RHHI-S into Target Language (GSRM-T1).

Instrument and Translator Information

	Source language: ENGLISH	**Target language: ASANTE-TWI**
Translator: F Translator 1 F Translator 2	Forward translator Name: ………………………….	Date: …………………
First language: ASANTE TWI	Forward translator profile: Aware of health status concept Naïve to concept	

Instrument Instructions

Source	Forward translated version
INSTRUCTIONS: The purpose of this scale is to identify problems your hearing loss may be causing you. ***Please select NO, SOMETIMES, or YES for each question. Do not skip a question if you avoid a situation because of your hearing problem. If you wear hearing instruments, please answer the way you hear <u>without</u> hearing instruments.***	**AKWANKYERƐ:** Nkyekyɛmu yi botaeɛ ne sɛ yɛbɛhunu nsunsuansoɔ a asosiiɛ bɛtumi de abrɛ wo. ***Mesrɛ wo, yi DAABI, ƐTƆ DA BI A, anaa AANE ma asɛmmisa biara. Mɛnnya asɛmmisa biara nto hɔ sɛ wosi wo tebea bi ho kwan ɛnam sɛ wowɔ asosiiɛ mu haw nti. Sɛ wode deɛ wɔde tie asɛm no hyɛ w'aso a, mesrɛ wo yi ano sɛnea wote no no berɛ a adeɛ a wɔde tie biara <u>nni</u> hɔ.***

Item content					
Item #	**Source**	**Forward translated version**			
			Daabi	**Ɛtɔ da bi a**	**Aane**
1	Does a hearing problem cause you difficulty when listening to TV or radio?	Sɛ woretie TV anaa radio a, ɔhaw a wowɔ no wɔ otie mu no ma no yɛ den ma wo anaa?			
2	Does a hearing problem cause you difficulty when attending a party?	Sɛ wokɔ apontoɔ bi ase a, ɔhaw a wowɔ wɔ otie mu no ma no yɛ den ma wo anaa?			
3	Does a hearing problem cause you to feel frustrated when talking to members of your family?	So otie mu haw ma w'abam bu berɛ a wo ne w'abusuafoɔ retwetwe nkɔmmɔ anaa?			
4	Does a hearing problem cause you to feel left out when you are with a group of people?	Otie mu haw ma wote nka sɛ wɔapo wo berɛ a wo ne nnipakuo bi wɔ hɔ anaa?			
5	Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?	Berɛ a worekɔsra wo nnamfo, w'abusua, anaa wo fipamfoɔ no, ɔhaw a wowɔ wɔ otie mu ma no yɛ den ma wo anaa?			
6	Do you feel handicapped by a hearing problem?	Otie mu haw ma wonya atenka bi sɛ woadi dɛm anaa?			
7	Do you feel that any difficulty with your hearing limits or hampers your personal or social life?	Wote nka sɛ ɔhaw a wowɔ no wɔ otie ho no ha w'ankasa anaa wo ne nnipakuo bi abrabɔ anaa?			

8	Does a hearing problem cause you to feel uncomfortable when talking to friends?	Ɔhaw a wowɔ no wɔ otie mu no mma wo ho ntene wo berɛ a wo ne wo nnamfo redi nkɔmmɔ anaa?			
9	Does a hearing problem cause you to avoid groups of people?	Otie mu haw ma wogyina so po nkurɔfokuo bi anaa?			
10	Does a hearing problem cause you to visit friends, relatives, or neighbors less often than you would like?	Otie mu haw no mma wo kwan mma wonsrasra wo nnamfo, w'abusuafoɔ, anaa w'afipamfoɔ sɛdeɛ anka wopɛ sɛ woyɛ no anaa?			

Adapted from Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. Ear & Hearing, 41 (1). 95-105.

APPENDIX IX

Forward Translation into Target Language (GSRM-T2).

Instrument and Translator Information

	Source language: ENGLISH	**Target language: ASANTE-TWI**
Translator: F Translator 1 F Translator 2	Forward translator Name: …………………………	Date: …………………
First language: ASANTE TWI	Forward translator profile: Aware of health status concept Naïve to concept	

Instrument Instructions

Source	Forward translated version
INSTRUCTIONS: The purpose of this scale is to identify problems your hearing loss may be causing you. ***Please select NO, SOMETIMES, or YES for each question. Do not skip a question if you avoid a situation because of your hearing problem. If you wear hearing instruments, please answer the way you hear <u>without</u> hearing instruments.***	**AKWANKYERƐ:** Nkyekyɛmu yi botaeɛ ne sɛ yɛbɛhunu nsunsuansoɔ a asosie bɛtumi de aba wo so. ***Mesrɛ wo, fa DAABI, ƐTƆ DA BI A, anaa AANE ma asɛmmisa biara. Mmɔ ntra asɛmmisa bi sɛ wode bɛsi wo tebea bi ho kwan ɛnam sɛ w'asoteɛ mu haw bi nti. Sɛ wohyɛ asoteɛ ho adeyɔdeɛ a, mepa wo kyɛ wo bua no sɛdeɛ wote no no berɛ a <u>wonhyɛ</u> bi nso.***

Item content

Item #	Source	Forward translated version			
			Daabi	**Ɛtɔ da bi a**	**Aane**

1	Does a hearing problem cause you difficulty when listening to TV or radio?	Ɔhaw a wowɔ no wɔ otie mu no ma no yɛ den ma wo berɛ a woretie TV anaa radio?			
2	Does a hearing problem cause you difficulty when attending a party?	Sɛ wokɔ apontoɔ bi ase a, ɔhaw a wowɔ no wɔ otie mu no ma no yɛ den ma wo anaa?			
3	Does a hearing problem cause you to feel frustrated when talking to members of your family?	So otie mu haw ma w'abam bu berɛ a wo ne w'abusuafoɔ rekasa anaa?			
4	Does a hearing problem cause you to feel left out when you are with a group of people?	Otie mu haw ma wonya atenka sɛ wɔayi wo mu berɛ a wo ne nnipakuo bi te hɔ anaa?			
5	Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?	Berɛ a worekɔsra wo nnamfo, w'abusua, anaa wo fipamfoɔ no, ɔhaw a wowɔ wɔ otie mu ma no yɛ den ma wo anaa?			
6	Do you feel handicapped by a hearing problem?	Otie mu haw ma wonya atenka bi sɛ woadi dɛm anaa?			
7	Do you feel that any difficulty with your hearing limits or hampers your personal or social life?	Wote nka sɛ ɔhaw a wowɔ no wɔ otie ho no ha w'ankasa w'abrabɔ anaa wo ne afoforɔ nkitahodie mu anaa?			
8	Does a hearing problem cause you to feel uncomfortable when talking to friends?	Ɔhaw a wowɔ no wɔ otie mu no mma wo ho ntene wo berɛ a wo ne wo nnamfo redi nkɔmmɔ anaa?			
9	Does a hearing problem cause you to avoid groups of people?	Otie mu haw ma wogyina so po nkurɔfokuo bi anaa?			
10	Does a hearing problem cause you to visit friends, relatives, or neighbors less often than you would like?	Otie mu haw no mma wo kwan mma wonsrasra wo nnamfo, w'abusuafoɔ, anaa w'afipamfoɔ sɛdeɛ anka wopɛ sɛ woyɛ ma no boro so anaa?			

Adapted from Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. Ear & Hearing, 41 (1). 95-105.

APPENDIX X

Merged Translation (T12).

NHWEHWZMU A ZFA OTIE HO AKWANSIDIE NSAKRAMU - NYAREWA NHWEHWƐMU

Deɛ Wɔrehwehwɛ N'asom no Nɔma:: ______________________ Ɛda:_______________
- - - - -

AKWANKYERƐ: Nkyekyɛmu yi botaeɛ ne sɛ yɛbɛhunu nsunsuansoɔ a w'asosiɛ bɛtumi de abrɛ wo. ***Mesrɛ wo, yi DAABI, ƐTƆ DA BI A, anaa AANE ma asɛmmisa biara. Nnya asɛmmisa biara nto hɔ sɛ wosi wo tebea bi ho kwan ɛnam sɛ wowɔ otie mu haw nti. Sɛ wode deɛ wɔde tie asɛm no hyɛ w'aso a, mesrɛ wo yi ano sɛnea wote no no berɛ a adeɛ a wɔde tie biara nni hɔ.***

Nɔma	Asɛmmisa	Daabi	Ɛtɔ da bi a	Aane
1	Sɛ woretie TV anaa radio a, ɔhaw a wowɔ no wɔ otie mu no ma no yɛ den ma wo anaa?			
2	Sɛ wokɔ apontoɔ bi ase a, ɔhaw a wowɔ wɔ otie mu no ma no yɛ den ma wo anaa?			
3	So otie mu haw ma w'abam bu berɛ a wo ne w'abusuafoɔ retwetwe nkɔmmɔ anaa?			
4	Otie mu haw ma wote nka sɛ wɔapo wo berɛ a wo ne nnipakuo bi wɔ hɔ anaa?			
5	Berɛ a worekɔsra wo nnamfo, w'abusua, anaa wo fipamfoɔ no, ɔhaw a wowɔ wɔ otie mu ma no yɛ den ma wo anaa?			
6	Otie mu haw ma wonya atenka bi sɛ wotx sini anaa?			
7	Wote nka sɛ ɔhaw biara a wowɔ no wɔ otie ho no ha w'ankasa anaa wo ne nnipakuo bi abrabɔ anaa?			
8	Ɔhaw a wowɔ no wɔ otie mu no mma w'ani nnye berɛ a wo ne wo nnamfonom redi nkɔmmɔ anaa?			
9	Otie mu haw ma wogyina so po nkurɔfokuo anaa?			
10	Otie mu haw no mma wo kwan mma wonsrasra wo nnamfo, w'abusuafoɔ, anaa w'afipamfoɔ sɛdeɛ anka wopɛ sɛ woyɛ no anaa?			

Adapted from Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. Ear & Hearing, 41 (1). 95-105.

APPENDIX XI

Backward Translation 1 (GSRM-BT1).

Respondent number: ______________________ Date:_______________
- - - - -

GUIDELINES: The purposes of these sections are to identify some problems that can be caused by your hearing impairments. ***Please, select*** **NO, SOMETIMES, OR YES** ***for each question. Do not leave any question unanswered to hinder some condition because you have*** **difficulty in hearing.** ***If you use a hearing aid in your ears, please answer according to how you hear without any hearing aid.***

Number	Question	No	Sometimes	Yes
1	If you are listening to TV or radio, does the problem you have in hearing makes it difficult for you?			
2	If you go to a party, does the problem you have in hearing makes it difficult for you?			
3	Does difficulty in hearing discourages you when you are communicating with your family?			
4	Does hearing impairment makes you feel like rejected when you are with other people?			
5	When you are visiting your friends, family, or your neighbors, is it difficult for you because you are hearing impaired?			
6	Does hearing impairment makes you feel like you are not complete?			
7	Do you feel like any challenge you have in hearing affect you or the lives of other people?			
8	Does your hearing impairment make you unhappy when you are communicating with your friends?			
9	Do you reject people because of your difficulty in hearing?			
10	Do your hearing impairments not allow you to visit your friends, family, or your neighbors as how you wanted to do?			

Adapted from Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening Tool Based on Psychometric Reevaluation of the Hearing
Handicap Inventories for the Elderly and Adults. Ear & Hearing, 41 (1). 95-105.

APPENDIX XII

Back Translation 2 – GSRM-BT2

NUMBER…………. DATE: ……….

INSTRUCTIONS: The purpose of this measure is to identify problems you are having because of hearing loss. **Please, choose No, Sometimes or Yes for every question. Do not leave any question unanswered just because you restrain yourself due to your hearing impairment. If you put on your listening device, please answer according to how you hear when there is no listening device.**

	Question	**Yes**	**No**	**Sometimes**
1	Does your hearing impairment make listening to a TV or a radio set difficult?			
2	At parties, does your hearing impairment make things difficult for you?			
3	Does your hearing impairment make you feel disappointed when having family discussions?			
4	Does your hearing impairment make you feel rejected when you are with a group of people?			
5	Does your hearing impairment make visiting your friends, family or neighbors difficult?			
6	Does your hearing impairment make you feel incomplete?			
7	Do you feel that your hearing impairment affects yourself or your life and the lives of others?			
8	Does your hearing impairment make you feel unhappy when conversing with your friends?			
9	Does your hearing impairment make you reject people?			
10	Does your hearing impairment reduce the number of times you would have wished to visit your friends, family or neighbors?			

APPENDIX XIII

Approval from Komfo Anokye Teaching Hospital.

KOMFO ANOKYE
TEACHING HOSPITAL

P. O. Box
Kumasi - Ghana
Tel:
Fax:
Website:

Our Ref. No.: *KATH IRB/AP/101/22*

Your Ref... No:..

Komfo Anokye Teaching Hospital Institutional Review Board

12th September 2022

Mr. Sesi Collins Akotey
University of Ottawa
Faculty of Health Sciences
School of Rehabilitation Sciences
451, Smyth Road
Ottawa, ON K1H 8M5
Canada

Dear Mr. Akotey,

Ethics Approval

Protocol title:	Development of a hearing screening protocol for adult population in Ghana
Study site:	Ear, Eye, Nose & Throat directorate of the Komfo Anokye Teaching Hospital, Kumasi
Sponsor:	Self-funded

We write in response to your correspondence of 17th August 2022 requesting the Komfo Anokye Teaching Hospital Institutional Review Board (KATH IRB) to review the research study referenced above.

The proposed research study went through the Board review of 6th September 2022 and we are pleased to inform you that KATH IRB has given approval for the following study documents:

- *Protocol version 1.1 last updated 2nd March 2022*
- *Informed consent form, version 1.0 last updated 17th August 2022*
- *COVID-19 Consent Form Addendum version 1.0 last updated 17th August 2022*
- *Case report form version 1.0 last updated 17th August 2022*
- *Data transfer agreement*

Approval for the study is in effect until 11th September 2023 and it is the responsibility of the Principal Investigator to maintain the study in good standing at the Komfo Anokye Teaching Hospital. The Board anticipates to be notified of the actual start date of your project.

A Centre of Excellence

APPENDIX XIV

Approval from Korle Bu Teaching Hospital.

In case of reply the number
And the date of this
Letter should be quoted.

My Ref. No. KBTH/MD/G3/22
Your Ref. No.......................

KORLE BU TEACHING HOSPITAL
1923
Excellence in Healthcare

KORLE BU TEACHING HOS.
P. O. BOX
KORLE BU, ACCRA.

Tel:
Fax:
Email:
Website:

9th February, 2022

SESI COLLINS AKOTEY
UNIVERSITY OF OTTAWA
SCHOOL OF REHABILITATION SCIENCES
FACULTY OF HEALTH SCIENCES

SCIENTIFIC AND TECHNICAL COMMITTEE APPROVAL
PROTOCOL IDENTIFICATION NUMBER: KBTH-STC 000214/2021

The Korle Bu Teaching Hospital Scientific and Technical Committee (KBTH-STC), on 9th February, 2022 approved your submitted study protocol.

TITLE OF PROTOCOL: "Development of a Hearing Screening Protocol For Adult Population in Ghana"

PRINCIPAL INVESTIGATOR: Sesi Collins Akotey

This approval requires that you forward your approved document to Korle Bu Teaching Hospital –Institutional Review Board (KBTH-IRB) for the ethical aspect of the proposal to be assessed before the project can be initiated.

This STC approval is valid till 30th January, 2023

You may, however, request extension of the approval period, or renewal as the case may be, should the study extend beyond the stated period.

Upon completion, you are required to submit a final report on the study to the STC. This is to enable the STC ensure among others that, the project has been implemented as per the approved protocol. You are also required to inform the KBTH-STC and Research Directorate of any publications that may emanate from the research findings.

Kindly note that, should the need arise, the KBTH-STC or IRB may institute appropriate measures to satisfy itself that study is being conducted according to the highest scientific and ethical standards.

Please note that any modification to the study protocol without Scientific Technical Committee (STC) approval renders this approval invalid.

Sincere regards,

Prof. G. Obeng Adjei
Chairman, KBTH-STC

Cc: The Chairman, KBTH-IRB

APPENDIX XV

Approval from Centre for Hearing and Speech Services.

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF EDUCATIONAL STUDIES
CENTRE FOR HEARING AND SPEECH SERVICES
P. O. Box Winneba, Ghana

8th March, 2021

Sesi Collins Akotey
School of Rehabilitation Sciences
Faculty of Health Sciences
University of Ottawa

Dear Mr. Akotey,

Subject: Site Approval Letter

I acknowledge receipt of your request to conduct a research project entitled "Validation of the Ghanaian Hearing Screening protocol" at the Centre for Hearing and Speech Services (CHSS).

I am pleased to inform you that the Coordinator and staff of the CHSS appreciate and approve the request to conduct the data collection of your validation study at CHSS.

The methodology involved has been reviewed - the administration of self-reported (RHHI-S), the Ghanaian Digit Triplet test and pure tone audiometry. We feel that this project will enhance the role and mission of CHSS among its networks in the future.

CHSS is, therefore, willing to work with Mr. Akotey and the team by providing access to our audiological facility, staff support, recruit participants for the study and uphold all ethical guidelines that will govern any scientific research.

Additionally, we look forward to the you and your research team upholding all the COVID 19 protocols of our institution to ensure your own safety and that of the participants.

We welcome you and your team to CHSS and look forward to working with you.

Sincerely,

Yaw Nyadu Offei, (MPhil, MSc, PhD)
Coordinator/Audiologist/Senior Lecture
CHSS/UEW