## Comparing the effectiveness and relevance of using the Ling Sounds or the Ling-Madell-Hewitt Battery for verifying Child's/Young Person's speech perception with their hearing devices.

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## Abstract

Many Qualified Teachers of the Deaf (QToD) utilise the Ling Sounds as a tool to ensure child or young person's (CYP's) hearing device is working optimally (McDonnell, 2014). In March 2022, Madell and Hewitt outlined an additional 4 phonemes to complement the existing Ling 6 sounds as part of the Ling-Madell-Hewitt (LMH) battery sound check (Madell & Hewitt, The Ling-Madell-Hewitt (LMH) Test Battery, 2022).

This study is split into two parts: 1) CYPs response to the LMH Battery and the corresponding comparison of the LMH Battery and the Ling Sounds using action research; and 2) the use and application of the Ling Sounds and the LMH Battery amongst qualified professionals within the UK using an online questionnaire.

This study has not been able to draw a definitive conclusion on the effectiveness of the LMH Battery compared to the Ling Sounds due to the small sample size but there are indicators that the LMH Battery will supplant the Ling Sounds in time as more services are becoming aware of the LMH Battery. This small-scale study's results show that the additional 4 phonemes in the LMH Battery are not essential to the majority of CYP in this study as a sound check as the key errors tend to be in the Ling Sounds component of the LMH Battery

This study has highlighted that appropriate training of professionals is needed to ensure that the sound check (the Ling Sounds or the LMH Battery) is consistent throughout the country; otherwise, the effectiveness and comparability may be compromised due to the potential variations.

The study has also highlighted that there have been few, if any, peer-reviewed studies validating the Ling Sounds and the LMH Battery and has identified areas of further study.

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### Abbreviations

BAEA	British Association of Educational Audiologists
BATOD	British Association of Teachers of Deaf Children and Young
BATOD	People
BSL	British Sign Language
CI	Cochlear Implant
CSS	Cascading Style Sheets
СҮР	Child/Young Person
Ed Aud	Educational Audiologist
FTE	Full Time Equivalence
НР	Hearing Inclusion Provision (The name of the Hearing-
	Impaired Unit used in the author's Service)
HTML	HyperText Markup Language
IPA	International Phonetic Alphabet
Ling Sounds	The Ling 6 phonemes in listening check
I MH Battery	Ling-Madell-Hewitt Battery
Livit Dattery	(Low/Middle/High): the 10 phonemes in listening check
MAPning	Cochlear Implant Programs that optimize the functionality of
	the Cochlear Implant
MEAG	Midlands Educational Audiology Group
MJWL	Manchester Junior Word list
	Peripatetic Qualified Teacher of the Deaf (Non-standard
PQToD	terminology – only used in this study to distinguish the
	different roles that a QToD may have)
PWS	Personal Wireless System (Radio Aids)
QToD	Qualified Teacher of the Deaf
SiN	Speech in Noise
SSE	Sign Supported English (based on British Sign Language but
	with English grammar structure)
ToD	Teacher of the Deaf

	Unqualified Teacher of the Deaf (Non-standard terminology –
UqToD	only used in this study to distinguish between qualified and
	unqualified Teachers of the Deaf)

## Glossary

/ə/ Schwa	A neutral vowel
AB Word List	'Arthur Boothroyd' Word list contains 8 lists of 10 words with
AB WORD LISE	three phonemes in each word.
	An audiologist who works as a healthcare professional and
Clinical Audiologist	works with the Teacher of the Deaf and Educational
	Audiologist but is not a qualified teacher.
Ling to Ling	Ling phoneme presented in the sound check with an
	incorrect response that is also a Ling phoneme.
	Ling phoneme presented in the sound check with an
Ling to pop-Ling	incorrect response that is not a Ling phoneme (a response
	that is one of the 4 phonemes introduced by the LMH
	Battery).
Non-Ling to pon-	Non-Ling phoneme presented in the sound check with an
	incorrect response that is also a non-Ling phoneme (one of
Ling	the 4 phonemes introduced by the LMH Battery).
Phoneme	A unit of sound which makes one word different from another.
	Professional is used in this study to mean a Qualified
Professional	Teacher of the Deaf or Educational Audiologist, not in the
	generic meaning of 'professional'.
	The Educational Authority where Teachers of the Deaf and
Service	Educational Audiologists work – usually based on geographic
	location.

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## 1. Introduction

In May 2022, I became aware of the Ling-Madell-Hewett battery for checking the effective use of hearing devices (hearing aids and Cochlear Implants) via the British Association of Teachers of the Deaf Children and Young People (BATOD) magazine (Madell & Hewitt, The Ling-Madell-Hewitt (LMH) Test Battery, 2022). When I investigated whether applying it to my role as a Teacher of the Deaf & Educational Audiologist would be helpful and lead to better outcomes for the CYPs who I support, I was intrigued as whether it was an appropriate replacement for, or improvement on, the Ling Sounds so an investigation began.

#### 1.1. Background

Listening and speech go hand in hand for effective verbal communication but the transmission of thought and ideas between people is very complex. There are many layers within language from detecting a sound, to discriminating a sound and then comprehending a sound within linguistics covering phonology, morphology, syntax, semantics and pragmatics (Hickey, 2005). The effective use of language for anyone, especially a person with an atypical hearing level, does depend upon getting the right 'input' quality (and quantity). Audiologists use hearing tests to determine a person's hearing level, produce an audiogram and then set up a hearing device. It is then the role of the parents and Teacher of the Deaf and Educational Audiologist to monitor and provided feedback to the clinical audiologist for fine tuning. One of the most common ways for doing this is to use the Ling Sounds (Kelly, 2014). Recently an extension to the Ling Sounds has been published, the Ling-Madell-Hewitt battery. This study will evaluate the effectiveness of the Ling Sounds for verifying speech perception in CYPs compared to the Ling-Madell-Hewitt battery.

#### **1.2. Outline of Main Chapters**

This study will be looking at the Ling Sounds and the Ling-Madell-Hewett battery. Chapter 2 will review the relevant literature on both checking tools looking at their strengths and issues. Chapter 3 will outline the methodology used to collect data and will include recruitment, ethics, equipment and procedure. It will also investigate quantitative and qualitative methods of data collection and respective analysis. Chapter 4 will evaluate the results from the data collected. Chapter 5 will discuss the findings of this research. Chapter 6 will summarise the key findings and any potential further research. The Appendixes will include the ethics form, relevant data and supplementary information.

## 2. Literature Review

In considering literature for review, it is important to understand both the technical and biological aspects of the Ling Sounds, the LMH Battery and other similar hearing checks, the history and development of the Ling Sounds test, the differences between the Ling Sounds and the LMH Battery and the impact of using one or other as a checking tool. This literature review does not cover literature relating to audiological testing with clinical environments or requiring specialised equipment.

In approaching this literature review, I searched for relevant articles using Scopus, using search terms based on Ling, Ling Madell Hewitt, LMH, children language development, listening checks, listening screen and hearing aid checks. I restricted my review to English language abstracts, and omitted papers that which were only looking at non-Ling and non-LMH assessments. With the exception of the papers written by Daniel Ling, all the papers referencing the Ling Sounds were within the last 30 years and all the sources referencing the LMH Battery were within the last two years.

The literature review will comprise of several sections. Section 1 reviews briefly at how we make sounds in speech and their variations. Section 2 reviews the six Ling Sounds' history, frequency range, strengths and issues of the Ling Sounds as a checker. Section 3 reviews the Ling-Madell-Hewitt Battery's frequency range, strengths and issues using the LMH Battery as a checking tool. Section 4 will compare and summarise the two tools and the validity of literature sources.

#### 2.1. Phonemes in English

Speech is a form of communication. It is produced using the lungs, pharynx, velum, mouth, teeth, nasal cavity and tongue working together to emit a series of sounds that a listener can receive and decipher into an intelligible meaning. Each sentence in English is produced from a series of words. Each word uttered is made up of one or more phonemes. (Dictionary, 2017)



*Figure 1: Schematic Representation of the Vocal Organs (Rabiner & Juang, 1993)* The Received Pronunciation English dialect uses 44<sup>1</sup> unique phonemes (Roach, 2009). As there are more phonemes than there are letters in the English alphabet, in 1888 the International Phonetic Alphabet (IPA) was established for clarity in distinguishing between different phonemes and to allow for anyone to pronounce any word in any language. (Szczegielniak, 2015). The IPA is being updated all the time, as recently as 2015 (International Phonetic Association, 2015).

#### 2.2. The Ling Sounds

In 1976, Daniel Ling devised a quick and easy, technology-free method for assessing the frequency range of human hearing (Ling, Speech and the Hearingimpaired Child: Theory and Practice, 1976) (Ling, Hearing Aids and the Use of Residual Hearing, 1976). Ling determined that the following sounds would be appropriate to cover the frequency range of English speech (as noted in 'Standardisation and selection of phoneme delivery' section below) and be able to discriminate between the different phonemes. The Ling Sounds has been modified and tweaked over the years, especially for Cochlear Implants (CI) where the "oo" phoneme is sometimes changed to the "u" phoneme. (O'Donoghue, Nikolopoulos, & Archbold, 2000). Additionally, /m/ (mm) was added to cover the lower frequency was added to the "Ling 5" to make it the "Ling 6" in 1995 (Robb, Flexer, & Rose, 2005).

<sup>&</sup>lt;sup>1</sup> General American English has 38-40 phonemes and General Australian English has 44-45 phonemes.

Phoneme (English)	Phoneme -	Frequency Range(s) (Hz)			
(English)					
Mm	/m/	250-350	1000-1500	2500-3500	
Оо	/u/	200-500	650-1170		
Ah	/a/	225-775	825-1275		
Ee	/i/	150-450		2300-2900	
Sh	/ʃ/			1500-2000	4500-5500
Ss	/s/				5000-6000

Table 1: The Ling Sounds Frequency Range (McKarns, n.d.) (Zhang, Sun, & Li, 2017)

A visualisation of the Ling Sounds is shown below.



Figure 2: Visualisation of the Ling Sounds as shown in **Error! Reference source not found.** Table 1: The Ling Sounds Frequency Range (McKarns, n.d.) (Zhang, Sun, & Li, 2017)

A simplified version by Keen is displayed on an audiogram below with each phoneme's intensity. It must be noted that the frequency ranges for Figure 2 and Figure 3 below do not directly match each other but are in close proximity, this could be due to differences in the vocal ranges of the sources of data.



Figure 3: The Ling Sounds on an Audiogram (Keen, The Ling 6 Sounds Test, 2022)<sup>2</sup>

#### 2.3. Strengths of using the Ling Sounds

The Ling Sounds is a key component in the toolkit of many Teachers of the Deaf. It allows for a quick technology-free assessment of hearing devices/hearing of a participant whilst covering the key ranges of human hearing (McDonnell, 2014). The simplicity of the Ling Sounds allows it to be used in a range of situations including using with Personal Wireless systems (PWS) (such as Phonak's Roger & Oticon EduMic). The Ling Sounds are also a useful tool for ensuring comfort of a patient when fitting with hearing aids and getting the initial feedback during the hearing aid fitting (McKarns, n.d.)

The Ling Sounds also have a high validity for verifying the effectiveness of hearing devices fitting in the classroom and at home as any substantial changes to hearing/incorrect programming of hearing devices can be identified by errors made in identifying the Ling Sounds (Agung, Purdy, & Kitamura, 2005).

#### 2.4. Issues with the Ling Sounds

The Ling Sounds have been around for approximately 48 years and its use has permeated the professional practices of Teachers of the Deaf and Educational Audiologists around the world including America, Europe and Asia (Zhang, Sun, & Li,

<sup>&</sup>lt;sup>2</sup> "Red line: the likely threshold if the sound was copied when presented at normal voice level. It could be better than this but that is all that this test has demonstrated. The F2 of 'oo' does not need to be heard for the child to hear 'oo' (may be identified by hearing only the F1). All other sounds are presented as loud as when used at the beginning of a word e.g. 'Sue'. 'ah' is two simultaneous sounds (1st Formant just above 500Hz, 2nd Formant above 1kHz)" (Keen, 2022)

2017). While the Ling Sounds has a reputation for high validity and reliability, there is surprisingly little in evidence in literature except when mentioned as part of a range of phoneme assessments to support the perception of good validity (Agung, Purdy, & Kitamura, 2005). It may be hard to support the validity of the Ling Sounds worldwide as there are a number of potential issues to address.

#### 2.4.1. Standardisation and selection of phoneme delivery

There has not been an accessible computerised software that is used as a standard for the assessment of hearing comprehension using the Ling Sounds (Kilcullen, 2015). In fact, due to different languages using different range of phonemes, it is possible that the Ling Sounds phonemes may not be used in the language of the person being assessed which would make it harder for the recipient to identify the Ling Sound or the LMH Battery phoneme. For example, a Chinese version of the Ling Sounds replaces /ʃ/ with /ʂ/ as they do not use /ʃ/ phoneme (Zhang, Sun, & Li, 2017). Another version uses /u, ə, a, i, tc<sup>h</sup>, s/ as this covers the whole of the Mandarin speech spectrum (Hung & Ma, 2016). Furthermore, there are a range of dialects which can subtly change the way the phoneme is produced, for example; /u/ is used in standard American English and /ʉ/ (high mid vowel) (Zhang, Sun, & Li, 2017) or /ɔ/ (Hung & Ma, 2016) for Australian English as they do not tend to use the cardinal /u/ (Zhang, Sun, & Li, 2017).

A number of countries such as China and Australia have selected to use other phonemes that cover their respective speech sound ranges better than the original six Ling Sounds phonemes (Hung & Ma, 2016). However, this is not always used consistently as only 59% of Australian clinicians use /ɔ/ but 100% use the /u/ phoneme despite the use of /ɔ/ as a replacement to /u/ being recommended in 1990 (Agung, Purdy, & Kitamura, 2005). This indicates that some clinicians use seven phonemes as they are aware of the Australian dialect not using the /u/ phoneme and the other 41% are either not fully understanding the phoneme's frequency ranges or are sticking the original Ling 'six' without deviation.

Also, intonation can have a significant impact on the utterance especially in tonal languages and must be considered when carrying out any standardisation (Szczegielniak, 2015).

#### 2.4.2. Issues with the Delivery of the Ling Sounds

The Ling Sounds has straightforward instructions on how to deliver the six sounds which makes it easy for anyone to utilise and to determine if the participant gives the correct responses or not. The procedure for how to deliver the Ling Sounds can be found in Appendix 3: How to Perform the Ling Sound Check.

#### 2.4.2.1. Variants of the Ling Sounds Procedure

There are several variants to the procedure listed above.

- Distance from participant some recommend: 1 meter, 2 meters, 4 meters.
- Using the picture cards, example in Appendix 2: An Example of the Ling Six Sounds Picture Card
- Location of speaker in front, behind, to the side of participant
- Voice of speaker male, female or computer
- Using an acoustically permeable fabric that occludes the participant from seeing the speaker's mouth and jaw or having the participant closing their eyes
- Hearing devices programming setting
- Varying the phoneme intensity
- Repeating phonemes e.g. (/m/ /m/ /m/) before response from participant

(Central Institute For the Deaf, n.d) (Agung, Purdy, & Kitamura, 2005) (Alexander Graham Bell Association for the Deaf and Hard of Hearing, 2014) (Kelly, 2014) (Kilcullen, 2015) (Ling, Hearing Aids and the Use of Residual Hearing, 1976) (Rabiner & Juang, 1993) (Smiley, Martin, & Lance, 2004) (Zhang, Sun, & Li, 2017)

As noted above, there are several potential variations to delivering the Ling Sounds. It would be interesting to discover which variants are in general use by Teachers of the Deaf, Educational Audiologist, clinical audiologists and parents. The use of variations is an area that could be relevant and will form part of the data collection as indicated below in the 'Questionnaire Method' section.

#### 2.4.3. The use of the Ling Sounds as a Diagnostic Procedure

Determining if there is an issue with hearing the full speech frequency range and/or if any adjustments are needed on hearing device is best left to an audiologist who would have a greater understanding of the frequencies of the phonemes and how that would be coded into the programming of hearing devices. (McKarns, n.d.) However the Ling Sounds require very little interpretation to determine if there is a need to refer to an audiologist for further assessment (McDonnell, 2014). The Ling Sounds should not be used as a diagnostic or a validation tool but used primarily as a checking tool as the assessment is not comprehensive enough nor has it been proven as a validation tool (Keen, The Ling 6 Sounds Test, 2022).

#### 2.5. The Ling-Madell-Hewitt Phonemes

The Ling-Madell-Hewitt (LMH), also known as Low-Middle-High (LMH), is a 2021 further development of the six Ling Sounds phonemes with an addition of four phonemes. These four phonemes are /n/, /h/, /z/ and  $/d_{z}/^{3}$  (AG Bell, 2022)

Phoneme	Phoneme -	Frequency Range(s) (Hz)			
(English)	IPA Code				
N(uh)	/n/	250-350	1000-1500	2000-3000	
H(uh)	/h/			1500-2000	
Zz	/z/	200-400			4000-5000
J(ur)	/dʒ/	200-300		2000-3000	

Table 2: The Additional Four Phonemes from the LMH Battery Frequency Range (AG Bell, 2022)

#### 2.5.1. Strengths of using the Ling-Madell-Hewitt Battery

It is the case that more good quality data is likely to equate to a better model (West, 2011). This may imply that the LMH Battery is better at identifying phoneme discrimination as it is an extension of the Ling Sounds to have a range of ten different phonemes instead of six.

The initial development of the LMH Battery started in 2011 when Hewitt identified that Cochlear Implant MAPping<sup>4</sup> errors were not picked up using the Ling Sounds as the Ling Sounds were not sensitive enough in the mid-frequency range (Hewitt, 2011). The missing sensitivity is relevant not only for detection of the mid-frequency sounds but the identification of the subtle differences between phonemes (Lochner,

<sup>&</sup>lt;sup>3</sup> Note: sometimes /d<sub>3</sub>/ can be written as /dj/ as not all font styles are capable of the '3' symbol.

<sup>&</sup>lt;sup>4</sup> MAPs are programs that optimize the functionality of a cochlear implant.

Hewitt, Owen, & Madell, 2015) (Madell, Hewitt, & Rotfleisch, 2018). This would indicate that the LMH Battery would be a suitable upgrade or progression from the Ling Sounds.

#### 2.5.2. Issues with the Ling-Madell-Hewitt Battery

A significant Issue, at the time of writing, is that there is no clear way for a presenter to verify that the correct additional phonemes are used unless they know how to use the IPA notation correctly. For parents, Teachers of the Deaf and Educational Audiologists this could be problematic; no online examples of how to present the phonemes were found in either journals or on video hosting sites - A search was done on YouTube for 'Ling Madell Hewitt battery' and 'Ling Madell Hewitt 10 sounds' plus other derivatives, only the Ling Sounds results were returned.

#### 2.5.2.1. Issues with Delivery of the Ling-Madell-Hewitt Battery

The LMH Battery is delivered slightly differently to the Ling Sounds. The procedure can be found in Appendix 5: How to Perform the Ling-Madell-Hewitt Battery which can be used in conjunction with the LMH visual card as shown in Figure 19 below. Appendix 4: An Example of the Ling-Madell-Hewitt Battery Card



Figure 19: The Ling-Madell-Hewitt battery Picture Card

Appendix 5: How to Perform the Ling-Madell-Hewitt Battery there is a difference in procedure between the Ling Sounds and the LMH Battery means that making a direct comparison between the Ling Sounds and the LMH Battery difficult due to the two additional utterances of each phoneme as well as the additional phonemes. Furthermore, the instructions are minimal, there is no mention of distances or obscuring the face.

As there are potential variations on how one would deliver the LMH Battery , there are similar to the issues as those affecting the delivery of the Ling Sounds mentioned above in section Variants of the Ling Sounds Procedure. There are also differences between the method of delivery of the Ling Sounds and the LMH Battery; an example of this is a picture card which can be found in Appendix 4: An Example of the Ling-Madell-Hewitt Battery Card which should be used with the LMH Battery but not mentioned in the Ling Sounds instructions.

#### 2.6. The Ling Sounds and The LMH Battery Summary

# 2.6.1. The Frequency ranges of the Ling Sounds and the LMH Battery

The Ling Sounds and the LMH Battery frequency ranges as given in Table 1: The Ling Sounds Frequency Range (McKarns, n.d.) (Zhang, Sun, & Li, 2017) Error! Reference source not found. and Table 2: The Additional Four Phonemes from the LMH Battery Frequency Range respectively are the average for normal American English speech sounds, and do not factor in differences between languages, dialects and, importantly, gender, which is relevant as men's voices typically have lower frequencies and women's voices tend towards higher frequency in the range for each phoneme (Kelly, 2014) (Raphael, Borden, & Harris, 2007). Different sources also cite slightly different ranges for each phoneme (McKarns, n.d.) (Zhang, Sun, & Li, 2017) (Madell & Hewitt, The Ling-Madell-Hewitt (LMH) Test Battery, 2022). The differences in the reporting ranges of each phoneme can potentially be attributed to different countries and accents of the local population (Wells, 2001). It would be interesting to look at the frequency ranges of each phoneme and determine if there is significant overlaps and uniqueness to verify the range of hearing is 'checkable' with either the Ling Sounds or the LMH Battery; this could be investigated in further detail which may be outside of the scope of this study which will focus in identifying the effectiveness of the Ling Sounds and the LMH Battery, and their use by QToDs and Ed Auds.

#### 2.6.2. Validity of Literature Sources

It is important to note that no peer-reviewed articles about the LMH Battery itself were found and very few peer-reviewed articles about the issues of the Ling Sounds (Hewitt, 2011) were found despite the Ling Sounds being cited in many papers and PhD theses.

There have been several non-peer-reviewed articles about the LMH Battery such as articles in BATOD and online on the home page of one of the authors (Jane Madell) and linked professional organisations (Madell & Hewitt, The Ling-Madell-Hewitt (LMH) Test Battery, 2022) (Madell & Hewitt, The LMH Test For Monitoring Listening – Jane Madell and Joan Hewitt, 2021) (AG Bell, 2022). The author was sent an email

to ask for the relevant supporting papers for the expansion of the Ling Sounds to the LMH Battery, but no reply was received at the time of writing.

There have also been counter-claims about the appropriateness of using the LMH Battery as the Ling Sounds does cover the range of human hearing as stated by Keen in BATOD (Keen, The Ling 6 Sounds Test, 2022). From discussion with the Keen via email (Keen, Email Correspondence on Ling/LMH, 2022), it was clear that the information provided was a personal understanding collected from many years of working in the Deaf education sector.

#### 2.7. Conclusion

Despite the Ling Sounds being widely known by QToDs and Ed Auds, there is little literature on the effectiveness of the Ling Sounds, and their effectiveness in typical usage, and very little literature supporting the use of the LMH Battery. The outcome of this literature review has led me to consider the following areas of focus as the main strands for my study:

- Testing the additional effectiveness of the LMH Battery over the Ling Sounds.
- The actual usage and effectiveness of the Ling Sounds and the LMH Battery by QToDs across the country.
- The effectiveness of the LMH Battery over the Ling Sounds as implemented into actual working practices by QToDs across the country.

## Methodology

#### 2.8. Methodology review

Research is used to find out the things that we do not know by undertaking an activity in a systematic way; in this case, to investigate the effectiveness of using the Ling Sounds or using the LMH Battery with the four additional phonemes as the checking tool of choice (Walliman & Walliman, 2011) as implemented into actual working practices .

The key components to investigate are:

- The ease of carrying out the Ling Sounds and the LMH Battery.
- The relevancy of the data collected by the checking tools and its impact.
- The current usage and understanding of the Ling Sound and the LMH Battery among Teachers of the Deaf and Educational Audiologists.

There are several methods of collecting data; Interviews, Focus Groups, Questionnaires and Observations to name a few (Dawson, 2019). Each method has its pros and cons, so the most realistic method or methods need(s) to be selected in order to acquire and analyse the data needed to answer the research question and key investigative components (Denscombe, 2003). Table 3: The Pros and Cons of Different Research Methods In Table 3 below is a key outline of the pros and cons of the main methods.

Research	Pro	Con
Methodology		
Interview	Can acquire in-depth	Few ToD/Ed Aud nearby,
	answers and a large amount	may have to travel/use zoom.
	of data	Takes a long time to do an
		interview and write up
		afterwards. Poor range of
		response from a population

Focus Group	Can acquire in-depth	Few ToD/Ed Aud nearby,
	answers and a large amount	may have to travel/use zoom.
	of data	Takes a long time to carry
		out and write up afterwards.
		Poor range of response from
		a population as a few
		participants available at the
		same time
Questionnaires	Can get lots of responses	Must wait for survey to close
	from the target population	before analysing results.
	so a good sample size. Can	Participants may not be as
	be done online for free. Can	honest. Can only ask a
	ask a range of closed and	limited number of questions
	open questions – medium	otherwise participants may
	depth of information	not complete questionnaire.
Observations	Can acquire in-depth	May not be
	answers and a large amount	applicable/relevant for this
	of data	research type as not easy to
		compare against other
		observations
Action Research	Can acquire in-depth	A very limited number of
(primary data	answers and a large amount	participants can be involved
collection)	of data. No other method	due to geographical
	suitable for collecting	limitations and can be time
	primary data from	intensive.
	participants.	

Table 3: The Pros and Cons of Different Research Methods (Dawson, 2019) (Denscombe, 2003)

As there are several elements that need to be investigated, the research will be split into two distinct strands. The primary strand will be the collection of empirical evidence from the action research. The secondary strand will be the collection of data from Teachers of the Deaf and Educational Audiologists by an online questionnaire. This was chosen due to time constraints and the difficulty in conducting enough interviews to get sufficient relevant data.

Using two (or more) different methods of data collection allows triangulation to reduce risk of bias from the researcher, this leads to a more robust study, thereby increasing the confidence in the data collected despite the data coming from two very different sources (Bell & Waters, 2014).

#### 2.9. Action Research Method

Reviewing the range of methods available to answer, 'The ease of carrying out the Ling Sounds and the LMH Battery' and 'The relevancy of the data collected by the checking tools and its impact' research aims would require significant primary data as the LMH Battery is such a new screening tool that there is no available data available to analyse. This would necessitate that primary data be collected in order to do a comprehensive analysis (Dawson, 2019) (Denscombe, 2003). The LMH Battery has a simple and clear set of instructions to carry out the check which will be followed so there is no variation between students (Madell & Hewitt, The LMH Test For Monitoring Listening – Jane Madell and Joan Hewitt, 2021). The data collection was started in December 2022 and completed in January 2023. The recording of the data is explained below in 'Record chart' on page 32.

#### 2.10. Questionnaire Method

Reviewing the range of methods available to answer "The current usage and understanding of the Ling Sounds and the LMH Battery among Teachers of the Deaf and Educational Audiologists" research aim, led to the selection of an online survey, in order to get responses from the widest range of the ToD/Ed Aud population. This will allow most of the QToD/Ed Aud population the opportunity to respond so that the researcher can see a statistically relevant sample snapshot of the usage of the Ling Sounds and the LMH Battery within the UK. An online survey is free so there would be no cost implication and would be more likely get responses compared to a postal survey (Dawson, 2019). There are several different sub-variants of data collection sampling such as; Random Sampling, Stratified Sampling, Systematic Sampling etc. For this survey, a Random sampling was taken as this would more likely give a representative of the population rather than trying to limit the number of participants as there is a very small population of ToD (Denscombe, 2003). As there are only approximately 1000 fte Qualified Teachers of the Deaf (CRIDE, 2022) of which a much smaller number are Educational Audiologists. The researcher would hope for a minimum response of 88 within this population to make the data statistically relevant (population size of approximately 1000, Confidence level of 95% and a margin of error of 10%) (Survey Monkey, 2022) (Francis, et al., 2010). The survey was sent out via email via BATOD and BAEA (British Association of Educational Audiologists) representative to reach the largest possible eligible members in the shortest space of time. Sending by email may also gather more responses due to the snowball effect as it can be passed on to people who are not be on the original mailing list (Newby, 2014).

With a survey, it is important that questions are clear, unambiguous, and straightforward with either open responses or closed responses that cover the full range of potential responses that the question may elicit (Denscombe, 2003). Before the survey was published, the questions were reviewed by peers to ensure clarity.

The survey was published in December 2022 and closed in January 2023; a copy of the survey is available in Appendix 12: The Survey distributed to Qualified Teachers of the Deaf and Educational Audiologists.

#### 2.11. Participants

#### 2.11.1. Participants – Primary Strand – Students (CYP)

As 'action research' is being carried out, there need to be appropriate participants, relevant to the criteria.

The requirements are:

- Hearing aid or Cochlear Implant user
- Primary language is English and uses oral communication (BSL/SSE usage is not relevant)

- School age and attending one of the local authority's Hearing Inclusion Provisions (HIP)
- Not implanted (CI) within the last year.

These criteria were established because the Ling Sounds and the LMH Battery are used within the Deaf oral education sector. Participants were restricted to those CYP that the researcher has access to as part of their role as the Provisions' Educational Audiologist and with whom the participants already are familiar. It is also important that the participant selected use auditory communication as the primary communication method as we are investigating auditory processing and not visual cues processing for this research.

## 2.11.2. Participants – Secondary Strand – Teachers of the Deaf & Educational Audiologists

A survey will be used and the results from the following criteria will be investigated.

The criteria are:

- Qualified as a Teacher of the Deaf and/or as an Educational Audiologist
- Working in the role of a Teacher of the Deaf and/or Educational Audiologist

These criteria were established because Teachers of the Deaf and Educational Audiologists have the background knowledge and may use the Ling Sounds and/or the LMH Battery as part of their role. The researcher will be able to look at the relevant professional engagement with these checking tools. It is important to note that different groups such as parents may give a more biased result as they may wish to "big" up their own child or emphasise difficulties whilst professional should be able to give a more unbiased view (Dawson, 2019).

#### 2.12. Ethics

All data collected from working with students as part of the primary strand was part of the researcher's normal working practice. Ethics approval was given to get consent to access the data. Ethics approval was given to create and access data via an online survey for the second strand. Ethics approval was sought from and given by the Research Ethics Committee, University of Hertfordshire. Copies of the approved documentation are included in Appendix 1: Ethics Forms. All student participants were made aware of their rights to withdraw from this at any time in both spoken English and written English before the data collection started. Written consent from parents was sought before data collection in the primary strand. In the second strand, consent was requested from, and given by, all participants in the first question of the survey. The Ethics Protocol number for this study is cSHE/PGT/CP/05747.

#### 2.13. Equipment

For this study, to ensure consistency as described in 'Procedure for the LMH Battery ' on page 33 below, the Ling Sounds and the LMH Battery will be delivered by prerecorded utterances using the Ewing Foundation SiN (Speech in Noise) set up as shown in Figure 4 below (Ewing Foundation, 2018).



*Figure 4: The SiN (Speech in Noise) Toolkit by the Ewing Foundation (Ewing Foundation, 2018)* This equipment was chosen as it can be calibrated so the volume intensity of the utterance of the Ling Sounds and the LMH Battery can be set to an appropriate speech level. Furthermore, there is a speaker in front rather than to the side of the participant, this ensures that the hearing devices will 'listen' to the sound in front (the cardinal direction) as shown in Figure 5 without any further adjustments due to the sounds being received by the hearing device from the sides as the sounds will also allow for checking of left and right sides without having to reposition the speakers as shown in Figure 6 below as the sounds will also be in the focused direction of the hearing devices.



Figure 5: A Hearing Devices May Adjust the Scope of its Focused Directionality Depending on the Hearing Device Programming. (ReSound, 2019)



Figure 6: The Focus of Hearing Devices Depending on Their Setting Including One-Sided Hearing Device (ReSound, 2019)

#### 2.14. Record chart

The responses are to be recorded on the individual 'LMH Randomised Order Check Sheet', an example of which can be found in Appendix 7: An example of the 'LMH Randomised Order Check Sheet'. To minimise memorisation or anticipation of the order of the phonemes, the order is randomised using excel programmed algorithm so there are two uses of each 10 phonemes and 2 blanks for silence. Furthermore, there was an additional restriction, that no consecutive phonemes are the same; for example, /s/ is not followed by /s/. Appendix 7: An example of the 'LMH Randomised Order Check Sheet' is one possible randomisation of the order.

#### 2.15. Web-Interface used for production of sounds

An interface was produced using HTML (HyperText Markup Language) and CSS (Cascading Style Sheets) coding language to mimic the straightforward interface of the SiN toolkit so that there is no additional learning for the user (Ewing Foundation, 2018). The interface incudes all the LMH Battery phonemes with the additional phonemes color-coded differently from the Ling Sounds phonemes. For each phoneme, the interface displays the phoneme (example: /ʃ/), a button which shows the non-professional sound (example: 'sh') three times to indicate the sound will be repeated three times, and an image corresponding to the sound from the LMH Battery card as shown in Appendix 4: An Example of the Ling-Madell-Hewitt Battery Card. This interface can be found in Appendix 8: The Web Interface for Producing the Ling Sounds/the LMH Battery

#### 2.16. Procedure for the LMH Battery

The procedure that will be carried out is straightforward as the participants are familiar with the researcher and the SiN set up so the interaction will not be different to previous visits. Once the written permission from parents has been received, confirmation will be obtained from the participants directly if they are happy for the use of their data anonymously in this study.

The initial hearing device checks discussion with the participant will be carried out and to ensure that there are no identifiable issues such as flat battery or blocked tube that will affect the results, and any such issues will be rectified. Then each of the phonemes will be played through the speaker while the participant is shown the related picture so that the student is aware of which picture relates to which phoneme as they will not have had any exposure to checks using the additional 4 phonemes in the LMH, nor to the Ling Sounds through a speaker. The phonemes will be played in the randomised order given on the participant's individual LMH record chart, and their responses recorded. This will be done with both hearing devices, right hearing device only, left hearing device only and with a Personal Wireless System bilaterally. Note: as mentioned previously, the Ling Sounds will not be checked separately as these are included in the LMH Battery so the relevant data will be extracted and then compared later.

A condensed version of the procedure is listed here:

- 1. Check hearing devices are of good working order.
- 2. Play the 10 phonemes showing the relevant picture.
- For each of bilateral, left, right and PWS set up adjust the participant's hearing device as appropriate and play the sounds in order as shown on relevant column the record sheet (and write down the response).

## 2.17. The Spectrographic data of the Ling Sounds Phonemes and additional LMH Battery Phonemes

Due to the phonemes being pre-recorded, the spectrographic (and formants) information could be analysed and compared to the information in the literature review above which is the commonly agreed average. The software used for this analysis is the Praat (Boersma & Weenink, 2022), with guides on the use of Praat from the University of York (Language and Linguistic Science, University of York, 2019) (Language and Linguistic Science, University of York, 2019), University of Toronto (Van Lieshout, 2003) and other sources (Wood, 1999). The range of the spectrogram was increased from 5000Hz to 10,000Hz to ensure that the full audiological range of speech is covered (DPA Microphones, 2021). The sounds were recorded in 'Audacity' (Audacity Team, 2022) using the computer's own built-in highquality microphone as the three external microphones used either distorted the sound or were too quiet<sup>5</sup> and overamplification<sup>6</sup> also distorted the sound. The voice for all recordings was the author who has a deep voice. In discussion with an audiologist and a SALT, several iterations of recordings were done with adjustments at each iteration to optimise the presentation of the phonemes (Marriage, 2022) (Doren, 2022). Over subsequent iterations, issues with the recording were identified and were addressed, such as; volume of presentations, duration of presentation,

<sup>&</sup>lt;sup>5</sup> USB & 3.5mm microphones

<sup>&</sup>lt;sup>6</sup> Phonak Touchscreen microphone

pitch of phonemes, and the difficulty in providing a sufficient duration of  $/d_3/$  phoneme which is impossible to sustain – this was resolved by adding a schwa vowel to give the duration required).

Silence was also used; this was created in Audacity and actually had some detection of high frequencies above 6kHz as shown in Appendix 9: Spectrogram of Silence. This range was compared and eliminated from selected sounds noted below.
#### 2.17.1. /m/ (mm) Phoneme



The /m/ (mm) phoneme has a very high energy in the first band, followed by high energy second band. There is a weak third band. This overall is slightly different to the standard range as shown in Table 4 below. It is considered by the IPA association as a *'Pulmonic bilabial nasal'* (International Phonetic Association, 2015)

	Band	Standard range	Vocal sample			
			range			
	Band	250 – 350 Hz	135 – 370 Hz			
	1					
	Band	1000 – 1500 Hz	1380 – 1750 Hz			
	2					
	Band	2500 – 3500 Hz	2000 – 2770 Hz			
	3					
	Table Bar	4: The /m/ (mm) Phonemodes (McKarns, n.d.) (Zhan	e -Table of Frequency g, Sun, & Li, 2017).			
	lt is inte	eresting to note that	there appears to			
be a small band of energy in the 4045 to						
4460 Hz range. I suspect that this is a						
harmonic as this is a multiple of the band 2						
	energy	intensity.				

#### 2.17.2. /u/ (oo) Phoneme



#### 2.17.3. /a/ (ah) Phoneme



Vocal sample

formant range

576 Hz

957 Hz

-

#### 2.17.4. /i/ (ee) Phoneme



#### 2.17.5. /ʃ/ (sh) Phoneme



The /ʃ/ (sh) phoneme has a very high energy in the first band, followed by high energy second band. There is a weak third band. This overall is different to the standard range as shown in Table 8 below. It is considered by the IPA association as a *'Voiceless palato-alveolar sibilant'* (International Phonetic Association, 2015)

	Band	Standard range	Vocal sample				
			range				
	Band	1500 - 2000 Hz	1800 – 2200 Hz				
	1						
	Band	4500 – 5500 Hz	7400 – 8200 Hz				
	2						
	Band	-	-				
	3						
	Table 8: The /m/ (mm) Phoneme -Table of Frequency Bands (McKarns, n.d.) (Zhang, Sun, & Li, 2017).						
	It is inte	eresting to note that	there appears to				
be a missing a large band of energy in the							
4500 to 5500Hz range, it appears to have							
	shifted up in frequency to 7,500 to 8,500 Hz						
	range.						

#### 2.17.6. /s/ (ss) Phoneme



The /s/ (ss) phoneme has a very high energy band above 4200 Hz. This overall is slightly different but is identifiable to the standard range as shown in Table 9 below. It is considered by the IPA association as a 'Voiceless alveolar fricative' " (International Phonetic Association, 2015)

Vocal sample

4200 – 6,000 Hz

range

-

-

#### 2.17.7. /n/ (nuh) Phoneme



#### 2.17.8. /h/ (huh) Phoneme



a very low energy in the first band. This overall is matching the standard range as shown in Table 11 below. It is considered by the IPA association as a 'Voiceless glottal fricative' " (International Phonetic

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#### 2.17.9. /z/ (zz) Phoneme



The /z/ (zz) phoneme has low energy in the first band, followed by higher energy second band. There is a weak third band. This overall is comparable to the standard range as shown in Table 12 below. It is considered by the IPA association as a 'Voiced alveolar sibilant fricative' (International Phonetic Association, 2015)

Band	Standard range	Vocal sample			
		range			
Band	200 – 400 Hz	160 – 450 Hz			
1					
Band	4000 – 5000 Hz	4000 – 5200 Hz			
2					
Band	-	-			
3					
Table 12:	The /z/ (zz) Phoneme -Ta (McKarns, n.d.) (Zhang, S	able of Frequency Bands Sun, & Li, 2017).			
I suspect that the 6KHz+ range which might					
be the background energy as noted in					
Append	lix 9: Spectrogram	of Silence.			

#### 2.17.10. /d<sub>3</sub>/ (juh) Phoneme



# 2.17.11. Summary of formants and energy band of phonemes in presentation



Figure 17: A Visualisation of all LMH Battery Phonemes with Respect to Literature (Orange) and Presentation Sample Determined by Spectrogram (Blue)

#### 2.18. Hypothesis

My hypothesis is that the use of the Ling Sounds and the LMH Battery phonemes do give the Teacher of the Deaf an element of information which they should consider in their reporting of the speech discrimination of a CYP, but they themselves are not the only method of verifying the quality of speech comprehension. I believe that the other assessments such as AB Word List or the Manchester Junior Word List would give more weight towards a referral<sup>7</sup> as these assessments also provide information on comprehension as well as discrimination of phonemes; however, as a screening tool both the Ling Sounds and the LMH Battery will serve their function to *indicate* that further assessment may be needed to verify the appropriateness hearing aid fitting/Cochlear Implant MAPping. Whether the Ling Sounds on its own or with the additional 4 phonemes in the LMH Battery would improve the quality of the checking tool would be interesting. However, I do not believe that the LMH Battery would provide sufficient additional information or identification of concern to warrant the

<sup>&</sup>lt;sup>7</sup> This is a referral back to audiology for a hearing/hearing device check, not an initial referral to audiology/service.

necessary training and development within the Services. A key component of this was my own difficulty in correctly enunciating the phonemes as described previously. I suspect that quite a few QToD and Ed Auds will have begun to use the LMH Battery due to the article recently published in the BATOD magazine in May 2022, without looking for any further verification from a peer-reviewed source.

#### 2.19. Conclusion

Effective methods of research have been chosen in order to answer, on a small scale, how effective the Ling Sounds and the LMH Battery are as a listening check, as they are used in practice by QToDs and Ed Auds across the country. With greater time, funding and access to more participants and to in-person contact with QToDs and Ed Auds a more comprehensive study could be carried out.

### 3.4. Results

This chapter contains the analyses of responses collected from the online survey, of professionals' working practices in use of the Ling Sounds and the LMH Battery, and of the results gathered during active research to evaluate the effectiveness of the Ling Sounds vs the LMH Battery as an appropriate hearing device checking tool.

#### 3.1. Primary strand

There are 18 students who attend the Hearing Inclusion Provisions (HIP) within the county in which the study has taken place. 16 parents gave permission for their child's data to be used. 2 students were removed due to eligibility rules as stated in Participants – Primary Strand – Students section above. This leaves 14 students whose data were used in this study. The students' ages range from 4 to 17 years old, covering Reception to Year 12 school year range. Most students are bilateral hearing instrument users and have either Hearing Aids or Cochlear Implants. All but two have a Personal Wireless System.

	Bilateral	l eft Aided	Right Aided	PWS (Bilateral)	Total		Error
Student ID	errors	errors	errors	errors	errors	Error ratio	percentage
1	8	7	4	6	25	25/88	28.4%
2	1	3	1	1	6	6/88	6.8%
3	0	0	0	1	1	1/88	1.1%
4	3	3	3	1	10	10/88	11.4%
5	5	3	2	4	14	14/88	15.9%
6	3	7	6	N/A <sup>a</sup>	16	16/66	24.2%
7	3	4	6	N/A <sup>a</sup>	13	13/66	19.7%
8	5	2	1	3	11	11/88	12.5%
9	0	2	1	3	6	6/88	6.8%
10	3	4	7	1	15	15/88	17.0%
11	2	3	1	5	11	11/88	12.5%
12	N/A <sup>b</sup>	6	N/A <sup>b</sup>	8 <sup>b</sup>	14	14/44	31.8%
13	4	4	3	2 <sup>c</sup>	13	13/88	14.8%
14	2	12	2	2	18	18/88	20.5%
Grand Total	39	60	37	37	173	173/ 1144	Average 15.1%

## 3.1.1. Error Rate by Students with Respect to Hearing Device(s) in use

Table 14: Errors Made By Each Student with Respect to Hearing Device in Use. Also shown in Chart 1.

<sup>a</sup> These students were not regular use of a PWS at the time of assessment.

<sup>b</sup> This student does not have a right hearing aid at the time of assessment (PWS is left only). <sup>c</sup> This student has a PWS on right side only, so PWS is unilateral.



Chart 1: Number of Errors for Each Hearing Device in Use by Each Student as Shown in Table 14**Error! Reference source not found.**<sup>8</sup>

Table 14 and the corresponding Chart 1 show, for the LMH Battery assessment as stated in the Procedure for the LMH Battery , the summary of errors that individual students made on presentations of each phoneme that they have been tasked to identify. Each phoneme was presented twice in a random order (but not sequentially) for each presentation group (Bilateral, Left Aided, Right Aided, PWS (Bilateral)). There are 22 presentations of the 10 different phonemes including two presentations of silence for each presentation group.

It is interesting to note that students 1, 5 and 8 made more errors with the bilateral presentation than the other presentations; I suspect that this is because the bilateral presentation was first and they are not used to the assessment process because they are in our lower school and may need additional conditioning to the process to be fully competent. Furthermore, students 10 and 14 have a substantial difference in their left-right hearing which would account for them a higher number of errors in the presentation when they were aided in only one of their ears. Student 14 also

<sup>&</sup>lt;sup>8</sup> All relevant charts have been set up to replicate audiology colours: Left is blue, right is red, free field is orange. Green was selected for PWS<sup>.</sup>

reported that for some presentations, he could hear the sounds in his non-aided right ear – this is consistent with their audiogram (not included in this study).

It is also interesting to note that students 9, 11 and 12 made more errors using their Personal Wireless System (Phonak Roger Touchscreen). This potentially could be caused by the dynamic gain of their PWS which could have distorted some or all of the phonemes enough that they were perceived as different phonemes. The presentation via PWS is discussed in the 'Personal Wireless System Results' on page 77 below.

Student 6, 7, and 12, do not have full bilateral PWS so not all of the presentation groups could be presented; this was reflected in Table 14 where the percentage reflects the error rate of actual number of presentations. It is of interest that student 12 who is a unilaterally aided, and has a high frequency ski slope hearing level had an over 30% error rate. Students 1 and 6 also had a high rate of errors. These students may have struggled with the sound check due to their young age and may need more practice with the non-Ling phonemes before doing the LMH Battery.

3.1.2. Breakdown of	Errors by Students w	ith Respect to Ling-only
and Non-Ling LMH		

Student ID	Ling to Ling Error	Ling to LMH Error	LMH to LMH Error	Other Errors	Grand Total
1	9	1	15	-	25
2	5	1	-	-	6
3	-	1	-	-	1
4	7	2	1	-	10
5	8	4	2	-	14
6	5	2	7	2 <sup>a</sup>	16
7	4	7	2	-	13
8	2	3	6	-	11
9	6	-	-	-	6
10	11	4	-	-	15
11	10	-	1	-	11
12	11	1	2	-	14
13	9	2	2	-	13
14	12	2	4	-	18
G Total	99	30	42	2	173

#### Table 15: Detailed of Student's Errors Broken Down by Ling, Non-Ling LMH or LMH.

<sup>a</sup> student reported a phoneme that was not on the LMH and did not select a picture.



Chart 2: Detailed of Student's Errors Broken Down by Ling, Non-Ling LMH or LMH.

The data in Table 15 and corresponding Chart 2, demonstrates that the majority of errors by most students tend to be confusion between Ling-only phonemes (/m/,/u/, /ah/, /i/, /ʃ/ and /s/) (Ling to Ling error). Students 1, 6 and 8 had more non-Ling LMH (/n/, /h/, /z/ and /d<sub>3</sub>/) confusion with other non-ling LMH (LMH to LMH error) phoneme errors while student 7 had more errors identifying Ling-only sounds with non-ling LMH sounds (Ling to LMH error).

However, as there are 6 Ling phonemes compared to the additional 4 LMH phonemes, a weighting was applied to see identify the error rate proportionally with respect to the number of phonemes in each assessment. The weighing of the Ling-only and non-ling LMH errors was given a 6:4 (3:2) ratio due to number of phonemes that correspond to the difference between the Ling and LMH.

Student ID	Ling to Ling Error	Ling to LMH Error	LMH to LMH Error	Other Error	Grand Total
1	9	1	22.5	-	32.5
2	5	1	-	-	6
3	-	1	-	-	1
4	7	2	1.5	-	10.5
5	8	4	3	-	15
6	5	2	10.5	2	19.5
7	4	7	3	-	14
8	2	3	9	-	14
9	6	-	-	-	6
10	11	4	-	-	15
11	10	-	1.5	-	11.5
12	11	1	3	-	15
13	9	2	3	-	14
14	12	2	6	-	20
Grand Total	99	30	63	2	194

Table 16: Weighted Detailed Student's Errors Broken Down by Ling, Non-Ling LMH or LMH.



Chart 3: Weighted Detailed Student's Errors Broken Down by Ling, Non-Ling LMH or LMH.

From Table 16 and Chart 3, we can see that despite the weighting, the non-Ling LMH phonemes only error rate was only higher for the same three students

previously identified as having a higher non-ling LMH only error rate and that the introduction of weighting did not make changes to the other students' highest or most notable error type. Two of the three students with their highest error rate in respect of non-Ling LMH only sounds are in reception class and the other student is in year 3.

	Phoneme Response												
		/m/	/u/	/a/	/i/	/ <b>ʃ</b> /	/s/	/n/	/h/	/z/	/dʒ/	-	Grand Total
	/m/	-	<mark>23</mark> a	5	5	-	-	6	-	2	-	-	41
þ	/u/	<mark>19</mark> a	-	-	5	-	1	-	-	10	-	-	35
nte	/a/	6	2	-	1	-	-	2	-	-	-	2	13
se	/i/	11	5	3	-	-	-	2	1	3	-	-	25
Pre	/ <b>ʃ</b> /	-	-	-	-	-	5	-	-	-	-	-	5
)e	/s/	-	-	-	-	8	-	-	1	3	-	-	12
en	/n/	4	-	1	-	-	-	-	1	-	-	-	6
on	/h/	8	-	3	-	1	1	6	-	-	2	-	21
РЧ	/z/	-	-	-	1	-	5	-	-	-	-	-	6
	/dʒ/	6	-	1	-	-	-	-	-	1	-	-	8
		-	-	-	1	-	-	-	-	-	-	-	1
Gr	and												
Тс	otal	54	30	13	13	9	12	16	3	19	2	2	173
Тс	otal <sub>Table</sub>	<b>54</b> 17: Bre	<b>30</b> eakdow	<b>13</b> vn of S	13 tuden	<b>9</b> ts' Re	12 spons	<b>16</b> es Erro	<b>3</b> ors with	<b>19</b> 1 Resp	<b>2</b> bect to P	<b>2</b> honei	<b>173</b> me Presentation

3.1.3. Breakdown of Errors by Students by Phoneme

<sup>a</sup> Significantly higher error count – highlighted for ease of identification.



Chart 4: Breakdown of Student's Response Errors with Respect to Phoneme Presentation.

From Table 17 and Chart 4, there is noticeably high number of errors where participants are confusing the /u/ (oo) and /m/ (mm) phonemes. There is also a high number of errors from students on the /i/ and /h/ presentations, but with a less consistent incorrect choice made. There are some errors on the other phonemes, but this is to be expected. It is interesting to note that there was an error on silence, this could be because the participant thought that there was a phoneme which they had missed so gave a random response.

There were 1144 presentations for all the phonemes (including silence) in this study, with an average error rate of 15.1% which would indicate that there is an expectation of 17 errors per phoneme. 6 different phonemes and the silence were below this average, two phonemes (/i/ and /h/) were slightly above this and two (/m/ and /u/) were more than double above this average.

However, on closer inspection, Student 14 reported all 8 presentations of /u/ as /m/ - this would indicate that there is a specific hearing or hearing device issue for this student. Disregarding errors made by student 14, the number of errors for /u/ is comparable with all the other phonemes except /m/which still had a higher number of

errors than other phonemes. This is shown in Table 32 and Chart 17 in Appendix 10: Breakdown of Errors by Students by Phoneme without Student 14 on page 100.

#### 3.1.4. Breakdown of Errors by Students with respect to the Ling Sounds or the LMH Battery

Collating errors which the student would have made had the Ling Sounds test been used from the wider group of errors made during the LMH Battery, and comparing to the errors made on the full LMH Battery, gives data as shown in Table 16 on page 52. There were issues about how to categorise the errors that were made outside of the Ling-only phonemes, in that where a student identified a Ling-only phoneme as a non-Ling LMH phoneme they were making a choice which would not have been possible had the Ling Sounds presentation been undertaken in its standard form; and therefore the student might not have made that error had only the more restricted options of the Lings sounds been available to them. Including all such errors could inflate the number of errors which would be found by the Ling Sounds presentation; conversely excluding them could underestimate the number of errors from such a presentation.

The error percentage was compared for each student due to some students having fewer phoneme presentations overall either because they had no PWS or were unilateral at time of assessment. In order to make a comparison between the Lingonly (6 phonemes) and the full LMH phonemes (10 phonemes), the minimum percentage of errors, 'Percent Error of Ling (Min)', was calculated using the number of 'Ling to Ling' errors and the total number of Ling Sounds phonemes presented while the maximum percentage of errors, 'Percent Error for Ling (Max)', was calculated for errors for Ling Sounds phonemes, regardless of incorrect phoneme response, and the total number of Ling Sounds phonemes presented. The true error for the student for the Ling Sounds would be somewhere in between the two values. The 'Percent Error for LMH' was calculated for all errors as all the phonemes are in the LMH.

Student ID	Percent Error for Ling (Min) <sup>9</sup>	Percent Error for Ling (Max) <sup>10</sup>	Percent Error for LMH <sup>11</sup>
1	16.1	17.9	28.4
2	8.9	10.7	6.8
3	0.0	1.8	1.1
4	12.5	16.1	11.4
5	14.3	21.4	15.9
6	11.9	21.4	24.2
7	9.5	26.2	19.7
8	3.6	8.9	12.5
9	10.7	10.7	6.8
10	19.6	26.8	17.0
11	17.9	17.9	12.5
12	39.3	42.9	31.8
13	16.1	19.6	14.8
14	21.4	25.0	20.5

Table 18: Percent Error by Student with Respect to The Ling Sounds or The LMH Battery Check Tool

As indicated in Table 18, there was a clearly higher percentage of error using the Ling Sounds rather than the LMH Battery for 8 students (colour coded green). For 3 students, their highest percentage error was on the full LMH (colour coded yellow). For the remaining 3 students the percentage error for LMH was between the minimum and maximum percentage error for Ling (colour coded orange) which implies that the true Ling Sounds percentage error could be similar to the LMH Battery percentage error, and could be higher.

If we look at difference in the percentage errors between the students, only student 1 was identified where the percentage error on the LMH is substantially higher than the respective Ling percentage error. For students 5 ,6, 7 and 10, the percentage error for Ling to non-Ling was noticeably higher than for the Ling-only and LMH . For the remaining 10 students the LMH and Ling error percentages are generally similar. However it must be noted that with more correct presentations from most of the students in the non-Ling LMH phonemes, this actually reduced the overall percentage error as shown by student 11 in Table 18 where the Ling-only error was 17.9% but the LMH error was 12.5% - this could potentially lead to a student not being referred back to audiology for further assessment as the student might be

<sup>&</sup>lt;sup>9</sup> Includes errors where Ling phoneme was presented, and an incorrect Ling phoneme response given; Ling to non-Ling errors are disregarded (but included in the 'Percent Error for Ling (Max)')

<sup>&</sup>lt;sup>10</sup> Includes all errors where Ling was presented irrespective of response

<sup>&</sup>lt;sup>11</sup> All errors

below the percentage for Teacher of the Deaf's potential referral criteria thus not triggering a referral to Audiology, where they would have been referred had only the Ling Sounds data been used.

#### **3.2. Secondary strand – Online Survey response**

The aim of this section of the study is to determine the responses from QToDs and Ed Auds to see the actual usage of Ling and LMH across the country and the effectiveness of LMH over LMH on actual working practices by QToDs and Ed Auds. All the questions can be found in Appendix 12: The Survey distributed to Qualified Teachers of the Deaf and Educational Audiologists on page 101.

#### 3.2.1. The Role and Education Sector of Respondents

Question 1 was to confirm that the participant has consented to this survey as outlined in the Ethics Approval in Appendix 1: Ethics Forms. Question 2 was a screening question to ensure that the participants meet the criteria as outlined in Participants – Secondary Strand – Teachers of the Deaf & Educational Audiologists section. Of the 80 responses received, 7 were from Unqualified Teachers of the Deaf (UqToD) and disregarded in the statistics due to the criteria excluding them, 73 were from Qualified Teachers of the Deaf. Of these 73, 15 also identified as Educational Audiologists<sup>12</sup> (qualified or unqualified). One Teacher of the Deaf also stated that they are a parent.

<sup>&</sup>lt;sup>12</sup> QToD – A person who only has the ToD qualification. Ed Aud – a person who also has the Ed Aud qualification as well as the QToD qualification but is not counted in the QToD results so we can compare QToD only qualifications with the QToDs *with* the additional Ed Aud Qualifications. "All Responses" or "Professionals" are both QToDs and Ed Aud together but excluding UqToDs.

Identified Work Setting	QToD	Ed Aud	Grand Total
Peripatetic	39	10	49
Peripatetic & Hospital	-	3	3
Peripatetic & Specialist school for the Deaf	1	-	1
Peripatetic & Resource base in a mainstream school	2	1	3
Resource base in a mainstream school	8	-	8
Mainstream school	3	-	3
Specialist school for the Deaf	5	-	5
Hospital	-	1	1
Grand Total	58	15	73

Table 19:Breakdown of QToD's and Ed Aud's Identified Work Setting

Table 19 shows the breakdown of QToDs and Ed Auds by their identified work placement. It is interesting to note that there are no responses from Ed Auds working in specialist schools for the Deaf and only one working in a dual role as a PQToD<sup>13</sup> and in a resource base. Conversely there a much higher number of QToDs working in these roles. It is also interesting to note that, of the respondents, only Ed Auds work in any hospital setting; this could be due to the specialist audiological understanding makes them more suitable for this role than a QToD. The ratio of number of respondent QToDs and Ed Auds working in a peripatetic role is comparable to the ratio of QToDs and Ed Auds nationally.

<sup>&</sup>lt;sup>13</sup> Peripatetic Qualified Teacher of the Deaf



The 69 responses to Question 4 show a trend amongst the professionals; they primarily use Ling with younger CYP however as the age range of the setting increases the proportion of professionals using Both Ling & LMH or LMH increases. The proportion of professionals using Ling or LMH reduces at almost every key stage; from 96% professionals using Ling/LMH in Early Years settings to 54% professionals in using Ling/LMH post-16 settings, with a noticeable drop from the beginning of the secondary setting (Year 7; age 11/12).





Chart 8: Responses by Professionals About Ling/LMH Variations and Record Keeping Based on this data, possibly because the Ling Sounds check has been around for over 40 years, there do seem to be several variations in how the Ling Sounds checks are carried out. It is interesting to note that there are 36 professionals will present the Ling Sounds in front of the CYP either 'all the time' or 'most of the time'. However only 25 professionals obscure the lip reading by asking the CYP to 'close their eyes' or 'use a fabric hoop' which would indicate that at least 11 professionals are permitting the possibility of CYP to lip-read as well as hear the Ling Sounds. It also must be noted that significant number of professionals are presenting the Ling Sounds from the side or behind the CYP at least 'some of the time'. This may lead to errors which would not be present in a front facing presentation as hearing devices tend to have adaptive programming to enhance speech sounds from *in front* of the CYP and not the side or behind.

3.2.3. A Comparison of Confidence and Training in delivering the	e
Ling Sounds and the LMH Battery Checks	

Responses	How confident are you in delivering the Ling Sounds?	How confident are you in delivering the LMH Battery?
Very Confident	42	10
Confident	26	28
Not Confident	5	19
I do not know how to deliver this test	0	28

Table 20: Professional's Responses Summary on How Confident They Are in Delivering Ling and LMH Phonemes The results from Table 20 clearly show that nearly all professionals are reporting that they are confident or very confident with using the Ling Sounds, conversely less than half of the professionals report that they are confident with the LMH Battery. A third of the sample report that they do not know how to deliver the full LMH Battery.

Responses	Have you had any training on how to deliver the Ling Sounds?	Have you had any training on how to deliver the LMH Battery?
Yes - I am happy with the training provided.	29	29
Yes - I have had training and I would like more	32	32
I use the sounds and am self-taught	19	18
I had no training and am not using the sounds	0	1

Table 21: Professional's Responses Summary on Their Training on Ling and LMH Phonemes

Table 21 does show that typically those who have had training in Ling also had training in LMH and those who are self-taught in Ling tend to be self-taught in LMH. Table 21 seems to be at odds with the results from Table 20; Table 20 shows that 28 professionals do not know how to deliver the LMH phonemes while Table 21 shows only one person is not using the LMH and all the other professionals are using the LMH even if they are self-taught.

Response	Yes - I am happy with the training provided.	Yes - I have had training and I would like more	I use the Ling Sounds and am self-taught	Grand Total
Very Confident	25	11	6	42
Confident	2	15	9	26
Not Confident	-	2	3	5
Grand Total	27	28	18	73

 Table 22: Confidence of Professionals in Using Ling Phonemes with Respect To Training Received for Ling

 Phonemes

Delving deeper into the responses of reported training and reported confidence in using the Ling Sounds as summarised in Table 22 above, the table shows that

reported confidence is linked to confidence in training. However, there are some professionals that are very confident despite being self-taught.

Responses	Yes - I am happy with the training provided.	Yes - I have had training and I would like more	I use the LMH Battery and am self- taught	I had no training and am not using the LMH Battery	Grand Total
Very Confident	4	-	6	-	10
Confident	-	4	12	-	16
Not Confident	-	-	3	16	19
I do not know how to deliver the LMH Battery	-	-	-	28	28
Grand Total	4	4	21	44	73

 Table 23: Confidence of Professionals in Using LMH Phonemes with Respect To Training Received for LMH

 Phonemes

Table 23 shows that those who have had LMH training are confident in the use of the LMH Battery phonemes. There are 18 professionals who are self-taught in the use of LMH who are confident or very confident in its use – this could be justifiable confidence because it is a 'straight-forward' check or misguided confidence as they are potentially delivering the LMH Battery phonemes incorrectly but without the input of another trained professional to verify if their delivery of LMH is correct.

Responses	Yes - I am happy with the training provided.	Yes - I have had training and I would like more	I use the LMH Battery and am self- taught	I had no training and am not using the LMH Battery	Gran d Total
Very Confident	4	-	5	-	9
Confident	-	4	9	-	13
Not Confident	-	-	1*	9	10
I do not know how to deliver the LMH Sounds	-	-	-	23	23
Grand Total	4	4	15	32	55

 Table 24: Professional's Confidence Responses in Using LMH Phonemes Who Reported Only Had Ling

 Phoneme Training

Further investigation of the professionals who had training in Ling but not LMH shows 8 professionals with the Ling Sounds training only are confident in delivering the LMH Battery despite not having the additional training. This could be professionals who feel the additional 4 phonemes in the LMH are not a barrier to them and feel that they could include this in their repertoire of phoneme checks. There is one person who is not confident in using the LMH Battery but has only had training on the Ling Sounds. All other professionals who are not confident in the LMH usage have not had any training.

Responses	I use the LMH Battery and am self-taught	I had no training and am not using the LMH Battery	Gran d Total
Very Confident	1	-	1
Confident	3	-	3
Not Confident	2	7	9
I do not know how to deliver the LMH Battery	-	5	5
Grand Total	6	12	18

Table 25: Professional's Confidence Responses in Using LMH Phonemes Who Reported No Training in Ling or LMH Phonemes

Delving further, Table 25 indicates that there are 18 professionals who reported to receiving no formal training in Ling or LMH, of whom 12 are not using the LMH and 6 are using the LMH phonemes of whom 4 are confident in their use. This does raise the questions, 'Should people use these checks without any training?' and 'Is self-learning (via YouTube/social media) an appropriate form for these listening checks?



#### Chart 9: Categorisation of Ling Training Received by Professionals

When professionals were asked where they got their initial Ling training, the responses were categorised as shown in Chart 9. The highest proportion learnt about Ling on their university course and a quarter from their Service – this could be because a large number of UqToD work in Service for a year prior to undertaking the university course leading to QToD status and therefore their Service may have introduced the Ling Sounds as it is part of the Service's working practice. There was one response that was unclear to the researcher. In Table 26 below is a selection of the responses given by professionals in response to the type of training received.

Response			
Category	Qualification	Selection of Comments	
University Course	QToDs	"Very basic whilst I was a trainee" "Ed Aud delivered training in the 6x Ling Sounds" "Peer training" "As part of TOD course"	
	Ed Auds	"Several times: QToD course, Ear Foundation Early Intervention course, by more experienced ToDs in school."	
Service	QToDs	"In house training" "From my predecessor as Ed Aud, also within my Ed Aud training. I have also trained colleagues in its use, on a roughly two-yearly basis, which helps refresh my knowledge and understanding of the assessment and the diagnostic aspect."	
	Ed Auds	"In-house training was delivered by the Lead professional many years ago. No refreshers since."	
	QToDs	"Some info via AVUK training and self-taught"	
AVUK	Ed Auds	"AV UK but some years ago and I've booked on some training in January to develop my knowledge further"	
Other Categorie <b>s</b>	QToDs	"Discussions with audiologist. Online SSC course. Modelling from colleague" "Training from Audiology and SLT at [Name Removed] Hospital."	
	Ed Auds	"Training from a specialist SaLT"	

Table 26: Selection of Comments by QToDs and Ed Auds with Respect to Initial Ling Phoneme Training



#### **3.2.4. Source of Original Awareness of the LMH Battery**

<sup>&</sup>lt;sup>14</sup> The questionnaire used 'the LMH Sounds' when this study uses 'the LMH Battery'

The responses to question 14 seem to vary highly between the QToDs and Ed Auds. It appears that 53% of Ed Auds found out about the LMH Battery from the BATOD magazine articles by Jane Madell and Joan Hewitt in March 2022 (Madell & Hewitt, The Ling-Madell-Hewitt (LMH) Test Battery, 2022) and by Peter Keen in May 2022 compared to 17% of QToDs (Keen, The Ling 6 Sounds Test, 2022). Most QToDs seem to be finding about the LMH Battery via their service (19%) or social media (17%) which is significantly more than for Ed Auds. There are 4 QToDs and 1 Ed Aud who were made aware of the LMH Battery for the first time in this survey despite the significant discussions within the BATOD and BAEA community.

### 3.2.5. The use of the Ling Sounds and the LMH Battery as Part of a

#### **Reporting Criteria**



Some of the QToDs and Ed Auds elaborated on their chosen answers; comments are in Table 27 below.

Response Category	Qualification	Selection of Comments	
Yes (All or Most of the time)	QToDs	"Yes - we use it to give evidence about how much a child appears to hear in different contexts in school"	
		"We share the information in our contribution to hearing review report"	
	Ed Auds	"We use Ling in audiology and rehab functional assessments and at key points along patient pathways"	
		"I contact audiology if Ling Sounds are consistently mixed up. E.g. /m/ and /oo/ [sic]."	
Some of the time	QToDs	"If we notice a pattern of a child not responding to a certain sound or several sounds we inform audiology or cochlear implant team so that they can reassess/ adjust"	
		"If a student incorrectly identifies or uses a sound in 3 or more trials (one per day), I contact the educational audiologist, and the clinical audiologist when I know who the child sees."	
		"It can do alongside an MJ word list. If sounds are missed or needing to be repeated we refer to audiology to check there haven't been any changes to hearing levels. Test box checks can help check hearing aids following Ling sound checks."	
	Ed Auds	"Yes, persistent difficulties at any specific loudness (and distance) are reported"	
		"If child suddenly struggling would email audiology"	

Other Categories did not have any relevant responses

Table 27: Comments Made by QToDs and Ed Auds in Response to Question 15 of the Survey

Responses to question 15 indicate that about 40% of QToDs and Ed Auds have some form of contact with the NHS audiology department to feedback any specific concerns of a CYP's hearing with regards to Ling/LMH. A large proportion of QToDs did not answer the question. It is interesting to note that Ed Auds were more explicit in their response in not contacting audiology compared to QToDs, in fact that 60% of Ed Auds indicated that they are not reporting Ling/LMH results back to audiology. Those professionals that do report data back to audiology tend to include the Ling/LMH as part of a report as supplementary information with other assessments such as MJWL (Manchester Junior Word List).

# 3.2.6. Responses by Professionals on their Service use of Ling/LMH

Categories of Responses	QToD	Ed Aud	Grand Total
Yes	14	3	17
- Using LMH	12	2	14
<ul> <li>Partial Adoption of LMH</li> </ul>	2	1	3
Discussed	5	4	9
- Trialling	3	3	6
- Unconvinced	1	1	2
<ul> <li>(Not Clarified)</li> </ul>	1	-	1
Νο	12	8	20
<ul> <li>Lack of Training</li> </ul>	5	3	8
- Unconvinced	-	1	1
<ul> <li>Unaware of LMH</li> </ul>	2	-	2
- Not sure	1	-	1
<ul> <li>(Not Clarified)</li> </ul>	4	4	8
Grand Total	31	15	46

 Table 28: Categorising the Responses of Professional's Services Adopting the LMH Battery with Breakdown of Reasoning



Chart 16: Categorising the Responses of Professional's Services adopting the LMH Battery with Breakdown of Reasoning.

The responses to the open-ended question on QToD and Ed Aud's service use of the LMH Battery was categorised into 'Yes', 'Under Discussion' (Discussed) and 'No' which were in turn broken down into sub-categories to indicate the difference within the main categories. It does appear that, proportionally, more QToDs are using the LMH Battery than Ed Auds of whom at least 50% are not using the LMH Battery either without giving a reason or due to 'lack of training' which is a strong indicator that they are waiting for more evidence that the LMH Battery has sufficient benefits to be worth the additional effort of investing in training. Table 29 below exemplifies some of the range of reasons why QToD and Ed Auds have given for using or not using the LMH Battery.

## Selected Comment Responses to Reasoning for Service Choosing Ling or LMH as Part of QToD/Ed Aud Working Practice

Testing them [LMH] out to see if they give us anymore/different information
I insist that my staff use one [Ling] or the other [LMH] - their chose[sic] which

We are happy with the Lings as a quick screen for whether or not [CYP's Hearing] equipment is working satisfactorily. We will consider the LMH test at some point but aren't convinced that it will add a great deal.

We use the Ling Sounds very consistently. ... I had already chosen to have a [CPD] focus on Speech tests ... will now include LMH sounds within this training.

Not sure [which the service is using; Ling or LMH], I have recently taken on the post

We do not use the LMH Sounds as we have not had training on how to test these, the pronunciation, etc.

I have always used Ling Sounds with preschoolers [sic] but have introduced LMH sounds with older pupils as part of daily listening checks more recently. We want to ensure that children have good access to speech

Useful for feeding back to NHS hearing aid providers to fine tune sound access from real world listening.

I need more info and training on the LMH sounds to then introduce to the team

We have just started using LMH this term. I am introducing it to my caseload.

Haven't got round to [using LMH] it yet due to other pressures but this questionnaire has given me the motivation to make it a priority after Christmas

We wanted to trial them to see if it helped to identify any issues that previously had gone unnoticed and to fill in missed frequencies that the other sounds didn't cover

We haven't used LMH yet as only just found out about it [in this survey].

We would prefer to have a training course on how to deliver the LMH sounds properly. Or at least a video demonstrating this. I am researching this now for the team and so far, not found anything.

We do use LING regularly. We are refreshing our audiology procedures at the moment and as part of this will look at speech discrimination and assess benefit of LHM test.

We use it because it is a really useful tool. In the past I've seen it flag up issues with cochlear implants that the child hasn't been able to tell us about / hasn't noticed.

We're currently trialling LMH sounds

[Not using LMH as] Not enough publicity and lack training

We find the LMH sounds more comprehensive than the Ling Sounds

Use LING to provide collaborative assessments with audiology and cochlear team. Also can give indication that CYP not accessing speech sounds Unaware of LMH sounds

We are not sure yet whether these would be more effective than the already established Ling Sounds and are waiting for feedback from colleagues trialling it in our service. I use the LMH sounds in an attempt to follow best practice guidelines.

We have been advised not to use LMH sounds until more research has been conducted and we are recommended by BATOD to use them

Hadn't considered LMH sounds as not had training.

Always use Ling-6 sounds. Trialling use of LMH sounds Ling Sounds used as good indication of detection, discrimination, hearing and production of sounds across frequencies [sic] Easy and quick to administer Easy to provide support and training to parents and key staff

 

 Table 29: Selected Comments on Reasoning for using the Ling Sounds or the LMH Battery within the Professional's Service and Working Practice

				l do not know		
	Very		Not	how to deliver	Gran	
Confidence of using the	Confide	Confide	Confide	the LMH	d	
LMH sounds	nt	nt	nt	Battery	Total	
We already use the LMH	10	13	1	1	25	
Battery	10	10	I		20	
We plan to use the LMH	_	ર	6	7	16	
Battery in the future		5	0	•	10	
We do not plan to use the	_	_	2	7	Q	
LMH Battery in the future			2	•	3	
We do not use the Ling						
Sounds or the LMH	_	_	6	6	12	
Battery but may consider			0	0	12	
using them in the future.						
We do not use the Ling						
Sounds or the LMH						
Battery and do not plan	-	-	-	2	2	
on using them in the						
future.						
Other Responses	-	-	4	5	9	
Grand Total	10	16	19	28	73	

Table 30: Confidence of using LMH With Respect to Professional's Service Use of Ling/LMH

Table 30 shows a strong link between the professional's confidence in using the LMH Battery and whether their Service is using the LMH Battery as part of their working. This indicated that those Services that are using the LMH will continue to do so while other Services are either not going to use the LMH Battery or are debating the use of the LMH Battery when there is more evidence to indicate that there should be a change. It is interesting to note that there are two professionals whose Service is using the LMH Battery but they themselves do not know how to deliver the LMH Battery or are not confident in doing so. Furthermore, there are Services that will use the LMH Battery, but professionals don't know how to use the LMH Battery or are not confident in their use yet - evidence that formal training should be provided to enable these professionals to develop their confidence.

Further Breakdown of the 9 'Other Responses' from Table 30 above.						
Confidence in LMH Response	Comments made by Professionals					
	I am planning to use/increase my use of LMH sounds in my practice - it would be good to discuss/implement as a whole service but this is limited at this time					
	Not sure [that the Service will use LMH in future]					
Not Confident	We do use Lings. We have considered LMH and have not reached a decision.					
	One element of our service is trialling the LMH sounds, but we do not know if this will yet result in more widespread usage.					
	We use ling but no plans to include LMH					
l do not know	I do not know if our school policy will change to [include] LMH sounds.					
how to deliver the LMH Sounds	I have never heard of them [LMH] and don't know if my service are [sic] planning on using them					
	First heard of them today!					
	Unknown [if the Service will use LMH in future]					

Table 31: Comments by 9 Professionals Who Responded 'Other Response' to Using The LMH Battery in their Service.

# 3.3. Summary of Results

In summary, students did make errors in the Ling Sounds check and LMH Battery, but these errors tended to be grouped with other phonemes with similar bands of sound such as /m/ (presented) to /u/ (reported) being the most common error followed by /u/ to /m/, /i/ to /m/ and /u/ to /z/. It is interesting to note that most of these errors tend to be in the lower frequency range (<1KHz) of human hearing rather than the higher frequency ranges and tend to be more in the Ling Sounds rather than the additional 4 phonemes in the LMH Battery. This potentially could lead to under-reporting of errors to Audiology if Services report using error percentage as a trigger.

Results show inconsistencies amongst professionals in how they deliver the Ling Sounds; use of the fabric hoop, position of voice (front, side or behind) and potential lip-readability. Another area of inconsistencies is how QToDs and Ed Auds acquire information; a smaller proportion of QToDs compared to Ed Auds get their information from the BATOD magazine and Services compared to social media. It is a similar picture when it comes to training; a larger number of professionals are selftaught, and this can potentially lead to incorrect usage of procedure.

There is also a divide amongst the professionals about the use of the LMH Battery in lieu of the Ling Sounds. Some Services have made the change to using the LMH Battery with training, others without the training, or are not using the LMH Battery. Some Services have indicated that they are researching and waiting for more information regarding the effectiveness of using either sound checks from peer-reviewed articles.

# 4. Discussion

This two-fold study set out to investigate the additional effectiveness of the LMH Battery compared to the Ling Sounds and the usage and effectiveness of the Ling Sounds and the LMH Battery by QToDs and Ed Auds across the country. This section will be discussing the results and the unforeseen issues from both strands.

## 4.1. Discussion on Primary Strand Results

This sub-section will be looking at the results from the LMH Battery carried out with the 14 CYPs.

## 4.1.1. Difficulty of reproduction of phonemes to consistent levels

Each phoneme is to be presented in a particular way but there were issues in creating the recording of the phonemes. The Ling phonemes are all easy to produce and sustainable in duration so that CYP can detect and discriminate the phonemes while some of the additional phonemes introduced in the LMH Battery are not sustainable in duration due to the nature of the phonemes (/h/,/n/) and  $/d_3/$ ). These phonemes needed a schwa (neutral vowel) to present the sound for a long enough duration that it is discriminable (Ashmead, 2008). Furthermore, discussion with both a SALT and audiologist about how to produce some of these sounds did result in several rounds of recording and adjusting (Marriage, 2022) (Doren, 2022). There also remained an issue with the /n/ which, based on available literature at the time of collecting results, could be presented as either 'nuh' or 'nnn'. The 'nuh' was used instead of 'nnn' as the 'nnn' was very similar to /m/ ('mmm'), to the extent that during pre-testing the difference was almost indistinguishable for hearing adults. There has been a further publication, by the LMH Battery creator, since collection of results which indicates that some of the Ling phonemes should be changed from what was established; /m/ from 'mmm' to 'muh' (HHTM, 2023). To overcome this, the creators would need to produce sound/video recordings on how to deliver this or give specific training.

## 4.1.2. Speech Perception – Recording Vs Live Voice differences

There has been a recent study by the Midlands Educational Audiology Group (MEAG) in which initial indications show that speech perception in the AB word list using recorded voice can have up to 40% drop in speech perception compared to the equivalent 'live' voice (MEAG, 2023); this variation in using recorded voice compared to live voice can affect the actual outcome of the results collected. Using the recorded voice would deliver the phoneme in a constant and repeatable way which could be considered beneficial from a scientific standpoint as it would reduce the number of potential variables and therefore the reproducibility and consistency of the outcomes for each CYP. However, while none of checks included in this study had the error percentages near or above the 40% variation found by MEAG, it does raise the question; would the results be impacted if a live voice had been used? Despite the inherent variation in live sound production, further investigation in this area is indicated.

## 4.1.3. Personal Wireless System Results

While it is known that CYP using PWSs tend to have positive outcomes in comprehension and tend to score better on word recognition than just using the hearing device (Weston, Cobbold, Statham, & Maiden, 2023), from Chart 1 and Table 14 on page 48, we can see that students 3, 9, 11, and 12 had a higher percentage error with the PWS than without. This indicates that 4 out of 12<sup>15</sup> students had a higher error rate with the PWS which would indicate that the PWS may not give any advantage to hearing or comprehension for these CYP and it may be better if the CYP did not use the PWS. However, listening through a radio aid (after the study was concluded), it appears that some of the phonemes sounds 'unnatural' (student 11) or 'weird' (student 9), which may be a contributing factor towards some students being less able to distinguish the sounds correctly via the PWS. This is another area, given additional time, could be investigated to ensure that the sound quality of the Ling/LMH are consistent when presented through the hearing device and through the PWS.

<sup>&</sup>lt;sup>15</sup> 14 students in total but two are not fitted with PWS at time of data collection.

## 4.1.4. Conditioning of CYP

There appear to be more errors by younger CYPs compared to older CYPs<sup>16</sup>. Consideration must be given to the conditioning process. It was noted that two CYPs did not appear to fully understand the task straightaway during the conditioning process but, during the main test, they did seem to register the full process. As the LMH Battery had not been presented previously by QToD/Ed Aud to any of the CYPs (as the service does not use the LMH Battery), they might not be as confident with the one round of conditioning before going into the assessment. Perhaps more conditioning, especially in the new phonemes from the LMH, would be appropriate, similar to the VRA (Visual Reinforcement Audiometry) conditioning process whereas many rounds of presentation are used as are needed to ensure conditioning (BSA, 2012).

# 4.1.5. The effectiveness of the Ling sound check and the LMH Battery based on the results

The key section of this study is to determine the effectiveness of both the Ling Sounds and the LMH Battery for use as the primary checking tool for determining whether the hearing device is delivering the full or consistent range of phonemes to the end user. From Table 18 on page 56 we can clearly see that for 11 out of the 14 CYP in this study, their error rate was higher on the Ling phonemes, and that the error rate was higher on the LMH phonemes for 3 CYP. However, we can see that for 2 of the 3 CYP, the difference between the Ling error rate and the LMH error rate is only 3% which is (up to) 2 additional errors on the LMH Battery out of the (up to) 88 presentations. In these cases, the error percentage for the LMH Battery is very close to that for the Ling Sounds and would be very unlikely to trigger a different outcome. The one CYP out of the 3 where the LMH Battery error percentage was higher than the Ling Sounds error percentage had an error rate 11% higher. The additional effort to learn and present the LMH Battery is high compared to the number of CYP for whom this would lead to a difference in the outcome following the sound check (7% in this study) may be considered excessive. The possible benefit of the LMH Battery is also dependent upon correct procedure and consistent methodology in the presentations. For this study, the LMH gain is marginal. This has

<sup>&</sup>lt;sup>16</sup> Student IDs not given as this may cause them to be identifiable.

potential to obfuscate an issue of device setting appropriateness, as the overall error percentage is lower. It could potentially mislead QToDs if the error percentage is lower with the LMH, so QToDs may not inform the CYP audiologist.

## 4.1.6. Other Points Raised from Primary Strand

It was interesting to note that the criteria for CYP selection as noted in 'Participants – Primary Strand – Students (CYP)' on page 29 did not account for students who were unilateral as opposed to bilateral hearing device users. Student 12 was unilaterally aided on the day of testing and he had a higher than average error rate which might be attributed to listening fatigue (Bess, Davis, Camarata, & Hornsby, 2020), it might be feasible in future to investigate the significance of bilateral compared to unilateral aiding in a future research project.

# 4.2. Discussion on Secondary Strand Results

This sub-section will be looking at the results from the online survey of QToDs and Ed Auds.

## 4.2.1. Confidence in data

As noted in 'Questionnaire Method' on page 28, 88 responses would have been required for the results to have a confidence level of 95% with an error margin of 10%. As there were only 73 responses that were accepted, this equated to a confidence level of 95% with an error margin of 11%, or a confidence level of 90% with an error margin of 9% (Survey Monkey, 2023). This is still an acceptable level of confidence in the data obtained, and so conclusions can be drawn.

## 4.2.2. Variation in presentation of Ling/LMH by QToDs

From Chart 8 on page 60, we can see that there are many variations in the application of the Ling Sounds from the method outlined in Appendix 3: How to Perform the Ling Sound Check on page 94 (Central Institute For the Deaf, n.d). These variations are not consistent, nor does one predominate. There is a large number of professionals who do not use an obscuring device or ask the CYP to close their eyes, so despite the Central Institute for the Deaf guidance of no *visual* guidance for the CYP, there seems to be a large number of QToDs who are

potentially allowing some CYP to have some visual guidance which could lead to inaccurate results. It is interesting to note that since Daniel Ling developed the Ling 5, subsequently expanded to Ling 6 sounds, there has been little validation of the appropriateness of theses checks, however Ling is still referenced in other literature (Ling, Speech and the Hearing-impaired Child: Theory and Practice, 1976) (Agung, Purdy, & Kitamura, 2005) (Hung & Ma, 2016) (Kelly, 2014). This could be because the Ling Sounds have been established for a long time (with its variations), or that it is ingrained into QToDs' and other professionals' working practices or the fact that they are a 'listening check' and therefore do not require as much scrutiny as an 'assessment', or for some other reason.

## 4.2.3. The use of the Ling Sounds and the LMH Battery by QToDs

In is interesting to note from Chart 9 that only 17% of QToDs heard of the LMH Battery from a professional source such as University course or BATOD publication compared to 53% of Ed Auds; this may indicate that Ed Auds interact more with professional sources of information and that QToDs who are not Ed Auds rely on their services and other social connections to understand and update their practices. On the other hand, 61% of QToDs are using the LMH Battery as part of their working practice compared to 53% Ed Auds. There appears to be a mismatch between where professionals learn about the LMH Battery and how frequently they are using the LMH Battery in their working practices as indicated in Table 28 on page 70 and Table 28 on page70. One of the things to consider is QToDs "jumping on the band wagon" because the LMH Battery is newer or "more" than what was established with the Ling Sounds. The potential use of the LMH battery due to its 'modern' or 'updated' nature without thorough understanding or training may be linked to the number of professionals who are using the LMH Battery despite having low confidence in their understanding of how to deliver it, as outlined in Table 20 on page 60.

# 4.3. Strengths and Limitations of Study

The method used in this study to collect data is one of the strengths of the study, as the method is repeatable and reliable due to the consistent procedure & set up, recorded human voice presentation of the phonemes, and tabulated recording of the results (Denscombe, 2003). This repeatability allows this study to potentially be scaled on a national level. However, with the recent development from the MEAG, the electronic presentation of the phonemes may actually be a weakness (MEAG, 2023) due to variability of the hearing devices and speaker generated sounds.

Carrying out the LMH Battery as the only sound check in this study and extracting the Ling Sounds results from only the presentations of phonemes present in the Ling Sounds, was more complex than originally envisioned due to the presence of error responses to Ling-only phonemes which could not have been made had the Ling Sounds been presented as a separate check and this lead to a three way analysis as shown in Table 18 on page 56. It could be advantageous to have done completely separate Ling Sounds and LMH Battery checks (on different days) to improve the validity of this study however this would have introduced additional variable elements. Table 18: Percent Error by Student with Respect to The Ling Sounds or The LMH Battery

The validity of some of the questions used in the survey (Appendix 12: The Survey distributed to Qualified Teachers of the Deaf and Educational Audiologists on page 101) may be questionable due to unanticipated slight ambiguity in the questions posed and the type of responses received from the QToDs indicating that they have not understood the question posed. For example, question 15 asks about referral back to audiology based on the Ling/LMH results but several QToDs say that they only get referrals *from* audiology which is the case when there is a newly identified CYP but the question used the term referral as when a QToD would request audiology to review a CYP based on the Ling/LMH results.

One of main limitations of this study is the timescale required to verify the recordings quality with both the audiologist and SALT – especially with some of the pronunciation of phonemes such as /n/ (nnn or nuh) and /d<sub>3</sub>/ (how to pronounce with or without a neutral schwa vowel). Furthermore, there wasn't an opportunity to verify the intended pronunciations with the author of the LMH Battery With the authors' latest publication on non-peer reviewed site aimed at parents, there is the potential for confusion over the phonemes which the authors intended to be used (HHTM, 2023) (Denscombe, 2003) (Dawson, 2019).

# **4.4. Potential for future studies**

As mentioned above, there are several potential avenues for future studies including but not limited to

- Are the Ling Sounds or the LMH Battery adequate as a listening check.
- Do the variations in the delivery of the phonemes change the accuracy of the check and impact potential outcomes.
- Would formal training in the delivery of the Ling Sounds/the LMH Battery be relevant to QToDs.

# 5. Conclusion

In conclusion, the additional effectiveness of the LMH Battery seems to be minimal compared to the Ling Sounds as, in this study, the main area for errors by CYP was in the Ling phonemes and not the non-Ling LMH phonemes. It must be noted that the Ling Sounds is incorporated into the LMH Battery so it is arguable that the LMH Battery could be superior to the Ling Sounds as it has a wider scope. However, there are difficulties such as *how* to present phonemes that must be clarified with recorded examples before the LMH Battery could become the dominant checking tool for QToDs and Ed Auds.

Currently the usage of the LMH Battery by professionals is growing but concerns, identified in this study, about the consistency of delivery technique and phoneme presentation could potentially lead the LMH Battery to be as variable as the Ling Sounds in their delivery and therefore not comparable between professionals.

The overall conclusion is that the LMH Battery has the potential to supplant the Ling Sounds but that there is currently no clear evidence to support the use of the LMH Battery as opposed to the Ling Sounds. In order for there to be a justifiable and reasoned switch of sounds checks, there has to be a more rigorous peer reviewed study on the benefits of the use of the Ling Sounds and the LMH Battery and a development of a proper accessible training tool to ensure consistent usage amongst professionals.

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# 7. Appendix

# Appendix 1: Ethics Forms SOCIAL SCIENCES, ARTS AND HUMANITIES ECDA

# ETHICS APPROVAL NOTIFICATION

**TO Dominic Caswell** 

CC Joy Rosenberg

FROM Dr Ian Willcock, Social Sciences, Arts and Humanities ECDA

Chair

DATE 04/11/2022

## Protocol number: cSHE/PGT/CP/05747

Title of study: Comparing the effectiveness and relevance of using the Ling or the

Ling-Madell-Hewitt sounds for verifying CYP speech perception with

their hearing devices

Your application for ethics approval has been accepted and approved with the following

conditions by the ECDA for your School and includes work undertaken for this study by the

named additional workers below:

no additional workers named

Conditions of approval specific to your study:

Ethics approval has been granted subject to the supervisor checking the following points

before any activity begins:

• The participant information sheet (EC6) was not included with the application the

letter to parents -(file titled EC3&6) currently omits most of the required material) -

this must be checked by the supervisor.

• Given that some of the children are teenagers, informed assent for their own participation should be sought from child participants (at an age-appropriate level).

• The survey for teachers must include information for participants and a means of recording explicit consent to participate (the template on pages 3 and 4 of this notification should be edited and used).

• The UH-provided Online Surveys system should be used for the questionnaire. Information on approved survey systems can be found here

https://www.studynet2.herts.ac.uk/ptl/common/ethics.nsf/Frequently+Asked+Question

s/B8C3196F1E5BF9BB8025837F003E58C3

• Survey results should be kept until the assessment process is complete (i.e. the exam board has met and confirmed final results). Test results should be retained according to school policy (as planned).

General conditions of approval:

Ethics approval has been granted subject to the standard conditions below:

Permissions: Any necessary permissions for the use of premises/location and accessing

participants for your study must be obtained in writing prior to any data collection

commencing. Failure to obtain adequate permissions may be considered a breach of this

protocol.

External communications: Ensure you quote the UH protocol number and the name of the

approving Committee on all paperwork, including recruitment advertisements/online requests,

for this study.

Invasive procedures: If your research involves invasive procedures you are required to

complete and submit an EC7 Protocol Monitoring Form, and copies of your completed

consent paperwork to this ECDA once your study is complete.

Submission: Students must include this Approval Notification with their submission.

Validity:

This approval is valid:

From: 04/11/2022

To: 28/02/2023

# Appendix 2: An Example of the Ling Six Sounds Picture Card



Figure 18: An Example of the Ling Six Sounds Picture Card (Harp, 2019)

Please note that there are several versions of the Ling Six Sounds pictures including variations in the images and with/without text/IPA symbols. This is just one example.

# Appendix 3: How to Perform the Ling Sound Check

If the child wears two hearing devices, put both of them on.

• Make sure both devices are turned on.

• Remove the coil or hearing aid at the right ear so the child is using only the left device.

• Place yourself next to or behind the child so she can hear you, but can't see your face.

• Say the following sounds one at a time and teach the child to repeat each sound after you

say it: "ah,""oo,""ee,""s,""sh,""m" Include a moment when you say nothing (silence).

• Each time you perform this check, say the Ling Sounds in a different order. Otherwise,

the child might memorize the sounds one way and just repeat them back, without actually listening for a prompt.

• Use unpredictable intervals of silence between each sound so the child has to respond

only after she hears you say something.

• Replace the coil or device at the right ear and remove the coil or device from the left

ear so the child is using only the right device.

- Repeat the Ling check with that device.
- Replace the coil or hearing aid so the child is now using both devices.
- Note any difficulty the child has repeating these sounds back to you with each device.

(Central Institute For the Deaf, n.d)

# Appendix 4: An Example of the Ling-Madell-Hewitt Battery Card



Madell and Hewitt, 2021

Figure 19: The Ling-Madell-Hewitt battery Picture Card (Madell J., Jane Madell, n.d)

# **Appendix 5: How to Perform the Ling-Madell-Hewitt**

## Battery

## How to Present the LMH Test

- Repeat each sound 3 times
- Try and make the length of the presentation equal with all the sounds
- Present them in random order

## Test with (See monitoring recording sheet)

- Right technology alone
- Left technology alone
- Binaural technology
- Binaural technology + remote microphone

nild:			Date:			
	Right Technology	Left Technology	Binaural	Remote Mic System	A3 A3 A3	
a						12
u					-	<i>.</i>
i					ee ee ee	sh sh sh
ſ					a	
s					55 55 55	mm mm mr
m					halo.	
n						
h					nn nn nn	hh hh hh
z					<u> </u>	÷,
dg						

# Appendix 6: An example of the LMH Data Sheet

Figure 20: An Example of the LMH Data Sheet Form (Listen With Lynn - Teachers Pay Teachers, 2021)

# Appendix 7: An example of the 'LMH Randomised Order Check Sheet'

	The LMH Randomised Order Check sheet (with Ling Sounds Marked)														
Nam	e of Stud	ent:											D	ate:	
The LIV	IH system -	eac	h sound to	be present	ed 3 times.										
	Bilateral	Set ı	μ		<b>Right Set</b>	up			Left Set	up		ilateral wit	h Personal	Wire	eless Syster
Sound	Phoneme	ling	Response by student	Sound	Phoneme	ling	Response by student	Sound	Phoneme	ling	Response by student	Sound	Phoneme	ling	Response by student
J(ur)	/dʒ/	-	brudent	00	/u/	*	stadent	ee	/i/	*	student	ah	/a/	*	brudent
00	/u/	*		zzz	/z/	-		nn	/n/	-		ee	/i/	*	
SS	/s/	*		sh	/ʃ/	*		ah	/a/	*		J(ur)	/dʒ/	-	
ee	/i/	*		zzz	/z/	-		SS	/s/	*		SS	/s/	*	
SS	/s/	*		J(ur)	/dʒ/	-		00	/u/	*				-	
00	/u/	*		sh	/ʃ/	*		mm	/m/	*		SS	/s/	*	
huh	/h/	-		nn	/n/	-		sh	/ʃ/	*		ah	/a/	*	
sh	/ʃ/	*		mm	/m/	*		zzz	/z/	-		nn	/n/	-	
ee	/i/	*		ah	/a/	*		SS	/s/	*		J(ur)	/dʒ/	-	
mm	/m/	*		SS	/s/	*		ah	/a/	*		00	/u/	*	
		-		huh	/h/	-				-				-	
nn	/n/	-		nn	/n/	-		J(ur)	/dʒ/	-		mm	/m/	*	
J(ur)	/dʒ/	-		mm	/m/	*		sh	/ʃ/	*		ZZZ	/z/	-	
		-		huh	/h/	-		huh	/h/	-		sh	/ʃ/	*	
zzz	/z/	-		SS	/s/	*		mm	/m/	*		ee	/i/	*	
ah	/a/	*		ah	/a/	*		zzz	/z/	-		00	/u/	*	
sh	/ʃ/	*		ee	/i/	*		J(ur)	/dʒ/	-		huh	/h/	-	
nn	/n/	-		J(ur)	/dʒ/	-				-		nn	/n/	-	
huh	/h/	-				-		ee	/i/	*		mm	/m/	*	
zzz	/z/	-		00	/u/	*		nn	/n/	-		sh	/ʃ/	*	
mm	/m/	*		ee	/i/	*		00	/u/	*		zzz	/z/	-	
ah	/a/	*				-		huh	/h/	-		huh	/h/	-	

Figure 21: APPENDIX: An Example of the Record Sheet to be Used When Determining the Order of Phonemes to be Played and Recording Responses as the Order Randomise on each Refresh with no Two Same Phonemes Being Next to Themselves.

# Appendix 8: The Web Interface for Producing the Ling Sounds/the LMH Battery

# LMH Battery

# Assessment

Use this to check the LMH sounds

#### Calibration

This is the calibration section - Use sound level meter - should present at 60dB at 75cm from speaker to ear





Figure 22: The Web-Based Interface for The Ling Sounds/ The LMH Battery.

# **Appendix 9: Spectrogram of Silence**

This spectrogram shows that the silence output from audacity programme also produced a quiet high frequency band of sound above 6KHz.



Figure 23: High frequency Spectrograph of Silence

This could be the background sound picked up by the microphone or also electronic noise created by the laptop when making a recording. Noted here for information.

# Appendix 10: Breakdown of Errors by Students by

Phoneme Response													
		/m/	/u/	/a/	/i/	/ʃ/	/s/	/n/	/h/	/z/	/dʒ/		<b>Grand Total</b>
	/m/	-	<mark>23</mark>	4	5	-	-	6	-	2	-	-	41
	/u/	<mark>11</mark>	-	-	5	-	1	-	-	10	-	-	35
ed	/a/	6	2	-	1	-	-	-	-	-	-	2	13
ent	/i/	10	5	3	-	-	-	2	1	2	-	-	25
res	/ʃ/	-	-	-	-	-	5	-	-	-	-	-	5
еΡ	/s/	-	-	-	-	7	-	-	1	3	-	-	12
e	/n/	4	-	-	-	-	-	-	1	-	-	-	6
u o	/h/	8	-	3	-	1	1	6	-	-	1	-	21
ЧЧ	/z/	-	-	-	1	-	5	-	-	-	-	-	6
	/dʒ/	6	-	1	-	-	-	-	-	1	-	-	8
		-	-	-	1	-	-	-	-	-	-	-	1
Gran	d Total	54	30	13	13	9	12	16	3	19	2	2	173

## **Phoneme without Student 14**

Table 32; Breakdown of student's Responses Errors with Respect to Phoneme Presentation Without Student 14



*Chart 17: Breakdown of Student's Response Errors with Respect to Phoneme Presentation Without Student 14* As mentioned in Breakdown of Errors by Students by Phoneme section, without student 14, the error rate for the /u/ presentation producing the /m/ error drops from 19 to 11 which is comparable to other phonemes.

# Appendix 11: The Phoneme ranges of the Literature compared to Voiced Presentation

	Literatur	e reported fr range	equency	Presentation Calculated frequency range				
Phonem e	Band 1	Band 2	Band 3	Band 1	Band 2	Band 3		
		1000-	2500-					
/m/	250-350	1500	3500	135-370	1380-1750	2000-2770		
/u/	200-500	650-1170	-	242	985	-		
/a/	225-775	825-1275	-	576	957	-		
/i/	150-450	2300- 2900	_	213	2750	_		
/ʃ/	1500- 2000	4500- 5500	-	1800-2200	7400-8200	-		
/s/	5000- 6000	-	-	4200-6000	-	-		
/n/*	250-350	1000- 1500	2000- 3000	135-400	1100-1750	2050-2631		
/h/*	1500- 2000	-	-	500-1600		-		
/z/*	200-400	4000- 5000	-	160-450	4000-5200			
/dʒ/*	200-300	2000- 3000	-	190-400	2000-2631	_		

 Table 33: The Phoneme's Frequency Ranges as Reported by Literature Compared to Presentation's Frequency

 Range (McKarns, n.d.; Zhang, Sun, & Li, 2017)

\* Additional phonemes introduced to the 6 Ling Sounds to make the LMH Battery

# Appendix 12: The Survey distributed to Qualified Teachers of the Deaf and Educational Audiologists

Below is the list of questions and potential answer options for the survey sent to Teachers of the Deaf and Educational Audiologist in the UK. (The questions are not numbered in the survey online, they are in the results and discussion sections of this document)

Do you consent to this survey? \* Required

 $\odot$  Yes

#### **Question 2**

## Page 2: About you and your role

What is your link to Deaf Education? Select all that apply (or closest match) \* Required

- Qualified Teacher of the Deaf
- □ Unqualified Teacher of the Deaf
- Educational Audiologist
- Audiologist
- Speech and Language Therapist
- □ Parent
- □ Other

#### **Question 3**

What setting do you work in? (Select all that apply) \* Required

- □ Peripatetic
- □ Resource base in a mainstream school
- Specialist school for the Deaf
- □ Specialist school (non-Deaf specialism)
- Mainstream school
- Hospital
- □ Other

## Page 3: Ling and LMH sounds

Note: Ling sounds are the 6 sounds - /m/ (mm), /u/ (oo), /a/ (ah), /i/ (ee), /s/ (ss), and /ʃ/ (sh)

The Ling-Madell-Hewett sounds (AKA: Low-middle-high) are 10 sounds:  $/d_3/(J)$ , /h/(h), /z/(zz), /n/(nn) and the 6 Ling sounds.

This part of the survey uses a table of questions, view as separate questions instead?

Use of Ling and LMH sounds

	Do you work with this age group?	Do you use the Ling 6 sounds with this group?	Do you use the LMH sounds with this group?
Preschool Children (Age 4 or less)			
Reception to Year 2 (Age 4-6)			
Year 3-6 (Age 7-11)			
Year 7-9 (Age 12-14)			
Year 10-11 (Age 15-16)			
Post 16 (Age 16+)			

Note: CYP = Child/Young Person/Student

Presentation of Ling and LMH sounds

Please don't select more than 1 answer(s) per row.

	All of the time	Most of the time	Some of the time	Never
Do you use a fabric hoop when you deliver the sounds?				
Do you ask the CYP to close their eyes when you deliver the sounds?				
Do you deliver the sounds from the side of the CYP?				
Do you deliver the sounds from behind the CYP?				
Do you deliver the sounds from the front of the CYP?				
Do you record your results?				

## **Question 6**

## Page 4: Ling Sounds

This section is looking just at the Ling 6 sounds only. The next section will be looking at the Ling-Madell-Hewett sounds.

How confident are you in delivering the Ling Sounds? \* Required

- Very Confident
- Confident
- Not confident
- $\,\odot\,$  I do not know how to deliver the Ling sounds

Have you had any training on how to deliver the Ling sounds? **\*** Required

- $\odot\,$  Yes I am happy with the training provided.
- Yes I have had training and I would like more
- $\,\odot\,$  No I use the Ling sounds and am self taught
- $\odot\,$  No I had no training and am not using the Ling sounds
- O Other

#### **Question 8**

If you have selected yes to the above question: Can you describe the training that you have received.

## Que<u>stio</u>n 9

## Page 5: Ling-Madell-Hewett Sounds (AKA Low-Middle-High)

How confident are you in delivering the LMH Sounds? \* Required

- Very Confident
- O Confident
- Not confident
- I do not know how to deliver the LMH sounds

Have you had any training on how to deliver the LMH sounds? \* Required

- Yes I am happy with the training provided.
- Yes I have had some training and I would like more.
- $\odot\,$  No I use the LMH sounds and am self taught
- No I had no training and am not using the LMH sounds
- O Other

#### **Question 11**

If you have selected yes to the above question: Can you describe the training you have received.

#### **Question 12**

Are you/your service planning on using the LMH sounds in the future? \* Required

- We already use the LMH sounds
- We plan to use the LMH sounds in the future
- We do not plan to use the LMH sounds in the future
- We do not use the Ling or LMH sounds but may consider using them in the future.
- We do not use the Ling or LMH sounds and do not plan on using them in the future.
- Other

#### **Question 13**

If applicable, when did you first find out about the LMH sounds?

if applicable, where do you first find out about the LMH sounds?

## **Question 15**

Page 6: Refer back to Hospital Audiology

Does the Ling or LMH sounds test form part of your criteria for referral to audiology, if so, what is your criteria? - Please elaborate


## **Question 16**

Do you have any comments on why you or your service have chosen/not chosen to use Ling or LMH sounds? - All responses are anonymous.

