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Malay Speech Intelligibility Test (MSIT) for Deaf Malaysian Children

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Abstract: This paper presents a novel approach to objectively measure speech intelligibility of deaf Malaysian children using nonsense syllables as test words. In this study, speech intelligibility of deaf children is measured through the ability to say simple syllables (consisting of a consonant and a vowel) for all the 22 Malay consonants. The MSIT score should indicate how well these children can produce speech; the higher the score, the better their speech intelligibility. The MSIT have been tested with twenty deaf and ten normal hearning Malaysian children and has been verified by five naïve and two expert listeners. The application of the test is presented as speech intelligibility index for deaf children in a deaf school. The successful development of the MSIT system serves to assist speech pathologist, therapist, teachers and parents of deaf children to determine the level of Malay speech deficiencies and the effectiveness of corrective measures taken.

Keywords: Malay Speech Intelligibility Test, deaf Malaysian children, Cued Speech, speech intelligibility, speech assessment, nonsense syllable

1.0 INTRODUCTION

It is estimated that about 2000 deaf children are born each year in Malaysia [1] [2]. Most deaf Malaysian children have very poor speech intelligibility, and in fact most of them are deaf-mute, a term continues to be used to refer to deaf people who cannot speak, or have minimum speaking ability. Reduced intelligibility severely compromises communication and social interaction for affected individuals. Although speech deficiencies in the deaf are quite difficult to overcome, learning to produce intelligible speech is not an impossible task. Studies have shown that deaf children receiving Cued Speech can acquire reasonable speech intelligibility, surpassing the majority of signing and oral children [using only amplified sound] in verbal language skills [3].

A reliable measure of speech intelligibility for deaf children is required for several reasons: to provide an index of the severity of speech disorder, to assist in treatment decisions, and to quantify changes which may result from intervention or treatment.

Several interval scaling methods have been developed to evaluate speech quality in general and these methods are also suitable to measure overall quality or speech intelligibility. Some of the methods exist for measuring speech intelligibility of deaf children are Mean Opinion Score [4], Attribute Estimation [5], Diagnostic Rhyme Test [5], Modified Rhyme Test [6], Cluster Identification Test [5], Phonetically Balanced Word Lists [4], Standard Segmental Nonsense Word Test [7] and more. In addition, several sets of sentences have also been used to evaluate the comprehension of speech. Sentences are usually chosen to model the occurrence frequency of words in each particular language. Unlike in segmental tests, some items may be missed and the given answer may still be correct, especially if meaningful sentences are used [8]. Among the sentence level tests are the Harvard Psychoacoustic Sentences [9], and the Semantically Unpredictable Sentences [10]. There are also different tests which can be used to measure proficiency specifically in the English language such as the Maryland Syntax Evaluation Instrument [11]. Malay word speech intelligibility measure using Mean Opinion Score was done by Tian et al. [12] in 2008. It wasn't meant for deaf children but instead for

Malay text-to-speech experiment. If this method is to be successfully used for deaf children, it requires the subjects to understand Malay words as well as the ability to pronounce three to four syllables word. At the moment, deaf children at the age of seven to twelve hardly understand Malay language, and normally having difficulties to pronounce words with more than two syllables.

Speech intelligibility measure for Malaysian children is a problem with many solutions, but still open because none of the current methods was designed specifically for indexing and monitoring deaf Malaysian children's speech. The current methods based on English language may have scored enough to be accepted as a suitable approach in some cases, however, far too little attention has been paid to such standard objective speech intelligibility test for use within the deaf Malaysian children training programme. This indicates a need to understand the various methods available for speech intelligibility test and to devise the appropriate system accordingly for deaf Malaysian children.

In this paper, Malay speech intelligibility measure using segmental nonsense word was adopted based on the following ideas. First, this nonsense words with vowel-consonant (VC) transition is one of the most commonly used evaluation method for speech intelligibility. Carlson [14] asserted that this method provides high error rates and informative diagnostic material especially when open response set is used. Second, the Malay syllables from the combination of 22 Malay consonants and a vowel /a/ test comprehensive range of articulation and phonetics skills for Malay children. Third, the use of nonsense mono-syllable words does not burden the children with vocabulary skills nor the pronunciation skills for more than one syllable words. And forth, the number of stimulus words to be used is kept to the minimum (22) taking into account the restlessness of deaf children when keeping them for too long in a session.

In this paper, deaf Malaysia children speech intelligibility was measured using Malay Speech Intelligibility Test (MSIT) system, a software programme that can record deaf children speech and produce a score that rate the intelligibility of the children. The recognition or scoring part was done using human assessor; both naïve and expert listener. A valid and reliable MSIT for measuring speech intelligibility will give the opportunity for deaf teachers and trainers the means to measure the effectiveness of their training programme. In addition, if a computer utilizing recognition engine can be used to effectively assess the children intelligibility, then it will open up the possibility of more home-based training, and less dependency to the scarce and expensive speech pathologist assessment.

The rest of this paper is organized as follows: In the next section, the background to the problem and the methodology are described. Then, computer implementation of the test procedures are presented, followed by the experimental results and analysis. The last section makes the conclusions and presents further works.

1.1 BACKGROUND

According to the Ministry of Education, at the moment, there are 283 schools in Malaysia with resources, teaching staff and facilities to help meeting the particular needs of the deaf children within the general school system. The government has officially adopted Bahasa Malaysia Kod Tangan (BMKT), a Malay sign language as the communication method to be used in these schools. As an alternative to the government hand-signed based special education for the deaf, the Cued Speech Centre (CSC) was set up by the National Society for the Deaf (NSD) in 1989, in collaboration with the Malaysian Council for Child Welfare at the latter's premises in Kampung Pandan, Kuala Lumpur. The CSC provides a nursery school (TASKA), preschool (TADIKA) and primary school in which Cued Speech in Malay (CSM) is used as the medium of instruction for deaf children in the Kuala Lumpur area. CSM is an adaptation of the American Cued Speech for use in the Malay language. It was prepared in September 1982, by Dr. Orin Cornett in collaboration with Mr. Tan Chin Guan, Vice President of the National Society for the Deaf, Malaysia (NSD).

Lengthy practical experience with the Oral-Aural Method until the late 1970's, followed subsequently by almost a decade with BMKT, has provided the NSD with an excellent opportunity for comparing the relative merits of these traditional methods with those of Cued Speech in Malay (CSM). According to Tan [13], from the observation obtained over the past twelve years, there was very little doubt that CSM was not only more practicable, but also far more effective than either the Oral-Aural Method or BMKT for the purposes of language acquisition by deaf children.

Perhaps, an even more important advantage of using CSM is that deaf Muslim children could be easily taught to say their prayers as well as read the Holy Quran in Arabic. On the other hand, this is not the case with deaf children who uses sign language. Without the ability to read text, one cannot expect them to perform their religious duties properly especially those that involves recitation such as prayer and reciting the holy Quran.

It is becoming increasingly difficult to ignore the contribution of Cued Speech in helping deaf Malaysian children to speak. A lot of work has been done on improving and developing efficient and individualized speech training methods. As a result, these children have shown the ability to speak up to a certain level of intelligibility. Although these phenomena of diversity in speech clarity or speech intelligibility exist in the school, there is no systematic approach to classify these children into speech intelligibility ranking and from then on develop these skills up to a certain standard accepted by the normal hearing person.

In this paper, MSIT system was designed and developed to demonstrate reliable measurement on the speech intelligibility level of the deaf Malaysian children. Hopefully, the MSIT system can be an effective tool in the sense that it will help to show that some children make faster progress on some aspects of speech learning and remediation than they otherwise could have made elsewhere.

1.2 OVERVIEW

In general, the evaluation procedure for speech intelligibility is usually done by subjective listening tests with response set of syllables, words or sentences. The test material is usually focused on consonants, because they are more problematic to synthesize than vowels [14]. In Malaysia, most software used for diagnosis and management of deaf children are based on the English language, which is unsuitable, given the great differences in the two languages. In non-phonetic language such as English, spelling often has little relation to actual pronunciation. Deaf Malaysian is more fortunate to learn Malay language which is easier due to the consistant speech sound of the Malay syllables.

Speech pathologists normally perform speech intelligibility test when they have an audience with deaf children. The test procedures conducted by these speech pathologists have two main shortcomings, namely a subjective evaluation and a capacity to be conducted and assessed only by trained professionals.

Development of the MSIT system in this study is focused on improvements in the following areas; objective evaluation, simple syllables, comprehensive, and able to be conducted and assessed by normal naïve listeners.

1.3 RESEARCH OBJECTIVES

The motivation for this research is that Cued Speech language would be potentially beneficial in aiding communication between members of the deaf community and the hearing community. The levels of speech for some children enrolled in Cued Speech Centre have reached the point of intelligible speech. Therefore, the MSIT developed in this research will be very useful to confirm this phenomenon. The test is also needed in order to place children into their appropriate proficiency level to facilitate the learning process, and to offer enough activities to enhance their Malay communication ability.

2.0 METHODOLOGY

To be able to perform an adequate experiment, some restrictions had to be made. The study only considers articulation of Malay spoken subjects, mainly children with hearing-impairment, with prolonged use of Cued Speech.

The study was conducted in the Cued Speech Centre (CSC), Kampung Pandan, Kuala Lumpur, the only school that offered primary school education for the deaf, with Cued Speech as a medium of instruction. The study samples are those children that have undergone prolonged used of Cued Speech for at least 2 years; that is all those in Standard 2 and above. Unfortunately, since a normal class size is around 5 to 10 pupils per class, the total number of sample would be around 20 to 25.

2.1 SUBJECTS

Twenty deaf subjects were selected from a group of children, age nine to thirteen, from the Cued Speech Center for deaf children in Kg. Pandan, Kuala Lumpur. They had pure-tone averages in their better ear over the frequencies of 500 Hz, 1 KHz, and 2 KHz ranging from 60 dB to 120+ dB (severe to profound hearing loss). Subject selection criteria includes the use of Cued Speech for at least three years as sole method of interpersonal communication, using hearing aids or cochlea implant and no evidence of other types of disabilities.

Ten normal hearing children were selected from a group of Malay children, age seven to twelve, studying in normal primary school in Malaysia. Their normal hearing is confirmed based on passing a simple Ling Six sound test.

2.2 MATERIALS

To examine speech intelligibility, a list of nonsense words was constructed using transitions between vowels (V) and consonant (C). Common examples of these methods can be found for example in Dutoit [16]. In this study, each nonsense word in the list of CV used the combination of a vowel /a/ and a consonant taken from 22 Malay phonemes (/b/, /c/, /d/, /f/, /g/, /h/, /j/, /k/, /l/, /m/, /n/, /p/, /r/, /s/, /t/, /v/, /w/, /y/, /z/, /sy/, /ng/, /ny/). The test words will be randomly generated to form CV nonsense

words, like /ta/, /ka/, /nga/ etc. A total of 22 words will be tested.

2.3 LISTENERS

The speech production of each child is audited by 5 normal naïve listeners and 2 speech therapists as judges. In this study, inclusion criteria for normal naïve listener judges are: (1) age between 18 and 40 years, (2) normal hearing and normal speech, (3) Malay as a native language, (4) no experience or minimal experience with the speech of persons with hearing impairment. The speech therapists must have at least one year working experience as speech pathologist or speech therapist in any local school, clinic or hospital.

2.4 PROCEDURES

The speech of the deaf children will be recorded on the computer system when they read a list of 22 random test words, one by one. There are 3 steps in administering this test: (1) production elicitation and recording, (2) playback for listener judges, and (3) scoring.

1 - Production elicitation and recording

The recording sessions will be conducted in a fair sound-treated room using a unidirectional dynamic microphone connected to a notebook computer situated on the same table. The experimenter will lead the subject through a series of recordings which will include the set of 22 nonsense words described above. The speech material will be typed in large print on the computer screen placed in front of the subject and the recording time for each word was set to 2s. The procedures was repeated for 10 normal subjects and 20 deaf subjects.

2 - Playback for listener judges

Speech assessment session will be presented to listeners through a computer, with listeners receiving a different order of presentation. They were instructed to listen careful to each word and to select the word they hear, the words that they thought the deaf subject was attempting to say, guessing if necessary. The presentation order of the pre-recorded words will be randomized. The listener will select a response alternative by mouse-clicking that alternative on the screen of the notebook computer.

There will be a set of 22 words from each subject. Each set of words will be presented at least once to each of the listener (The listener can listen to the sound again if needed, but the number of repeat listening allowed is only one). Thus, there will be a total of 660 presentations (production of words) from all 30 subjects for each listener. Data will be recorded using a program that keeps track of the presentation, the deaf subject, the word, and the listener's response. The above procedures will be repeated for 2 speech therapists and 5 normal hearing people.

3 - Scoring

The MSIT is meant to measure speech intelligibility ranking from 0% (worst - unintelligible) to 100% (best - intelligible). It consists of 22 words which were randomly generated to form CV nonsense words; /ba/, /ca/, /da/, /fa/, /ga/, /ha/, /ja/, /ka/, /la/, /ma/, /na/, /pa/, /ra/, /sa/, /ta/, /va/, /wa/, /ya/, /za/, /sya/, /nga/, and /nya/. For each syllable correctly guessed by a listener, the child will score (1/22) % which is about 5%. If the listener guesses correctly for all syllables, the child speech intelligibiliy is rated at 100%.

3.0 RESULTS AND DISCUSSION

Reference for intelligibility measure

How does one know the speech intelligibility rating of a subject so that the MSIT score can be compared to (validate)? If a subject is rated poor on his or her speech intelligibility, does a test score of 4 out of 10 justify this phenomenon? There are two groups of people who can confirm this measure; 1) speech therapists and 2) the deaf children teacher.

Prior to the test, all the subjects were rated by the teachers of the deaf and a speech therapist in Cued Speech Centre. The reason for the pre-rating is to compare the result of the test to the perception of the teacher to the subject. If the test score match the test results then the validity of the test will be highly supported.

Four teachers who taught the deaf child, and a speech therapist were asked to rate the speech intelligibility of the children based on their experience. There are only three categories; Unintelligible, Partially Intelligible and Intelligible. Table 1 below describes the category of the children speech intelligibility.

The teachers and the speech therapist mark on a paper the category of the deaf child as they seem fit. Table 2 shows the ratings of 20 deaf children in Cued Speech Center. The table shows the children speech intelligibility as perceived by four experienced teachers and a speech therapist at the center.

As can be seen from the table, fourteen children's speech was unintelligible, as the listeners could only understand their speech when they use Cued Speech. Five children's speech was partially intelligible since the listeners feel that the children need to use Cued Speech to further clarify certain words. One child was assessed to be intelligible as he was able to be understood even without using Cued

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Speech. It should be stressed that intelligible speech and normal speech are two different things. Even though deaf children speech is intelligible, the way they spoke normally does not indicate that they are normal. There are other things that differentiate normal hearing children and deaf children speech; among others are the nasality, voice tone, melody and emotions. The result indicates that the twenty children covered the range of mostly poor speakers as the selection of deaf speakers made in this study.

Table 1: Category rating of deaf children speech intelligibility in the Cued Speech Center.

	Category	Description
1	Intelligible	Able to be understood even without cuing
2	Partially Intelligible	Some of the spoken words need cuing to be understood
3	Unintelligible	Unable to be understood without cuing (Cued Speech).

Table 2: Results of the pre-assessment rating.

Subject	Gender	Age	Category	Score
1	Male	10	Unintelligible	5/5 (U)
2	Male	10	P.Intelligible	4/5 (P) 1/5 (U)
3	Female	10	Unintelligible	5/5 (U)
4	Female	10	Unintelligible	5/5 (U)
5	Female	10	Unintelligible	5/5 (U)
6	Male	10	Unintelligible	5/5 (U)
7	Male	11	P.Intelligible	3/5 (P) 2/5 (U)
8	Female	11	Unintelligible	5/5 (U)
9	Male	11	P.Intelligible	4/5 (P) 1/5 (U)
10	Female	11	Unintelligible	5/5 (U)
11	Female	11	Unintelligible	1/5 (P) 4/5 (U)
12	Male	11	Unintelligible	5/5 (U)
13	Female	12	P.Intelligible	4/5 (P) 1/5 (U)
14	Male	13	Unintelligible	5/5 (U)
15	Male	13	Unintelligible	5/5 (U)
16	Male	13	Unintelligible	5/5 (U)
17	Female	13	Unintelligible	5/5 (U)
18	Female	13	Unintelligible	1/5 (P) 4/5 (U)
19	Male	14	Intelligible	5/5 (I)
20	Male	14	P.Intelligible	4/5 (P) 1/5 (U)

It should be noted that the residual hearing of these children were not tested. Therefore, the relationship of the children residual hearing and speech intelligibility was also not part of this study, although in her research, Öster [15] showed that there are positive relationship between measured speech intelligibility and functional hearing of the children.

3.1 MSIT RESULTS

Figure 1 shows the result of the Malay Speech Intelligibility Test for 20 prelingually deaf children and 10 normal hearing children. The figure shows number of correctly perceived words in percent.

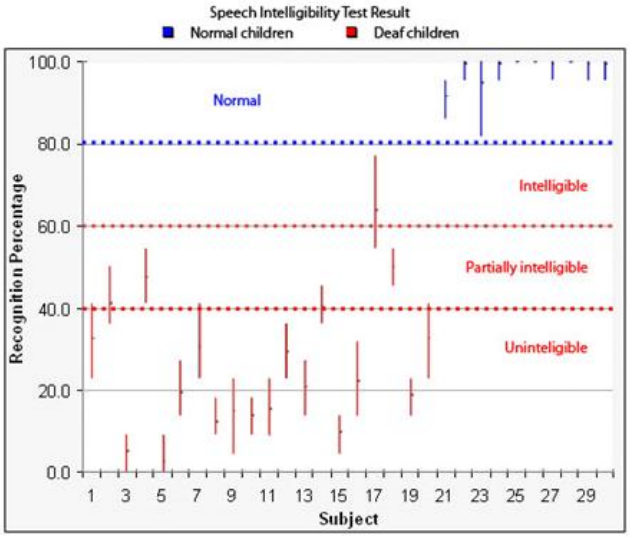

Fig. 1 Results of the MSIT. Each bar represents the minimum and maximum score by seven listeners for each of the subject.

From the plot we can safely say that the score for normal hearing children is between 80 to 100% whereas the score for deaf children is between 0 to 80%. The score for deaf children can be further broken down to three categories as shown in Table 3.

Table 3: Category of deaf children speech intelligibility based on MSIT score.

Category	**MSIT Score**
Intelligible (I)	between 60 – 80%.
Partially Intelligible (P)	between 40 – 60%
Unintelligible (U)	between 0 – 40%

If one were to compare the MSIT rating and the Experts rating from Table 2, one can see that the rating is 95% accurate as shown in Table 4.

In Table 4, there is only one child with rating disagreement between the expert and MSIT rating. Subject 7 was rated 'Partially Intelligible' by experts but was rated 'Unintelligible' using Nonsense Word's Test. Further observation on the results shows that Subject 7's score were not much further than the cut off score of 40% for 'Partially Intelligible' speech. The expert rating was also split 40/60 on 'Unintelligible/Partially' scale. With 95% accuracy, one can safely say that Nonsense Word Test's

score very much agree with the expert's score. This is one way to conclude that the test is valid.

Table 4: Rating Comparison for 20 deaf children in Cued Speech Center between the pre-assessment expert rating vs MSIT rating

Subject	Expert Rating	MSIT Score	MSIT Rating	Match ?
1	U	5	U	Y
2	P	47	P	Y
3	U	19	U	Y
4	U	14	U	Y
5	U	16	U	Y
6	U	29	U	Y
7	P	32	U	N
8	U	3	U	Y
9	P	41	P	Y
10	U	12	U	Y
11	U	31	U	Y
12	U	15	U	Y
13	P	40	P	Y
14	U	22	U	Y
15	U	10	U	Y
16	U	19	U	Y
17	U	21	U	Y
18	U	32	U	Y
19	I	64	I	Y
20	P	50	P	Y

In the research, intelligible speech for deaf children means that their speech can be understood by naïve listener but still their speech are not like normal children. There are still some aspect of their speech, for example, nasality and voice tone that differentiate them from normal hearing children. For those that receive MSIT scores between 40% and 60%, their speech are considered partially intelligible; i.e. naïve listeners need to pay special attention to their speech and sometimes have to figure out the missing consonants. Nonetheless, one can still guess what they are talking about. Speech therapist will have a much better chance of understanding them faster.

To test the extent of agreement among the two types of raters (naïve and experts) on each of spoken syllables, the following question need to be answered; "Is there a significant difference in MSIT scores between the two groups of human assessors (naive listeners and speech therapists)?". We start by stating our Null Hypothesis; "We assume there is no difference in MSIT scores between the two groups of human assessors". The Alternative Hypothesis, the one used if the Null Hypothesis is rejected, is therefore that there is some difference in MSIT scores betwen the two groups of human assessors.

Table 5: SPSS Analysis for 30 children's MSIT scores

Group Statistics

	CAT_RATE	N	Mean	Std. Deviation	Std. Error Mean
SCORE	Naive	150	50.3013	36.46305	2.97720
	Expert	60	49.8483	37.71892	4.86949

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
SCORE	Equal variances assumed	.173	.678	.081	208	.936	.4530	5.62490	-10.63613	11.54213
	Equal variances not assumed			.079	105.515	.937	.4530	5.70751	-10.86329	11.76929

In Table 5, in the Independent Samples Test table, we have two rows of data; which one to be use will depends on the result of Levene's Test for Equality of Variances, displayed in the first two columns. A significance value (Sig.) of 0.05 or more means that the Null Hypothesis of assuming equal variances is acceptable, and we therefore take the first line of the output; a significance value of less than 0.05 means that the second line of output should be used for the T-Test.

In this case, the significance value is comfortably above this threshold, and therefore equal variances are assumed. So, with a Significance Level of 0.678, we say that there is evidence, at the 5% level, to suggest that there is no difference in test scores between the two groups of human assessors (naive listeners and speech therapists). This is another way of confirming the validity of the MSIT.

There is yet another useful way of interpreting the results of the MSIT. If one were to table the results using Confusion Matrix, then one can easily see the tabulation of consonants that match between the questions and answers. A sample conversion matrix from the MSIT data is shown in Figure 2.

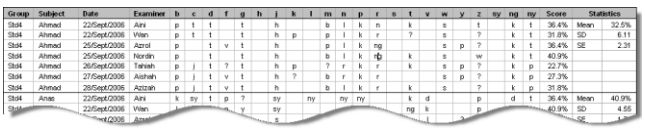

Fig. 2 Part of the conversion matrix for 30 deaf children's MSIT results.

As can be seen from the table, detail pronunciation errors of the subject are clearly shown. In the above example, subject Ahmad had difficulties in phonemes /b/, /d/, /g/, /j/,

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/m/, /n/, /p/, /r/, /w/, /z/, /ng/ and /ny/ where all examiners (listeners) misinterpreted his pronunciation.

3.2 SCREEN SHOT OF MSIT SYSTEM

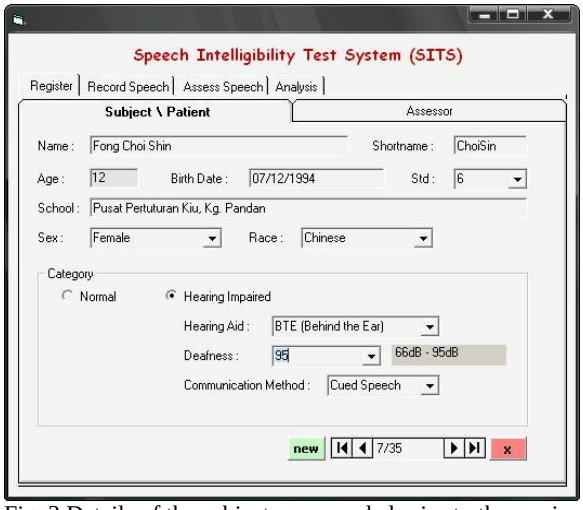

Fig. 3 Details of the subject are recorded prior to the session.

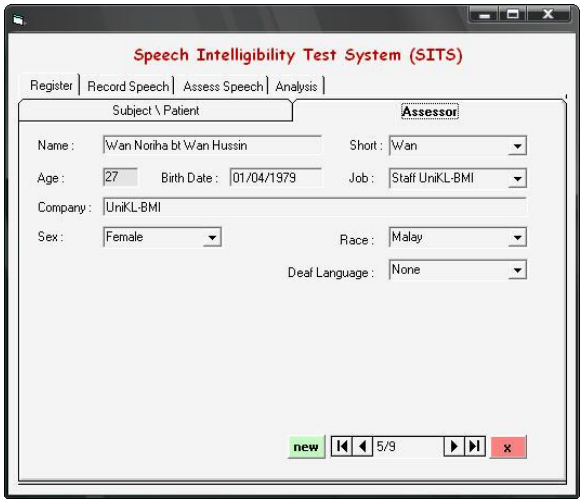

Fig. 4 Details of the assessor are recorded prior to the session.

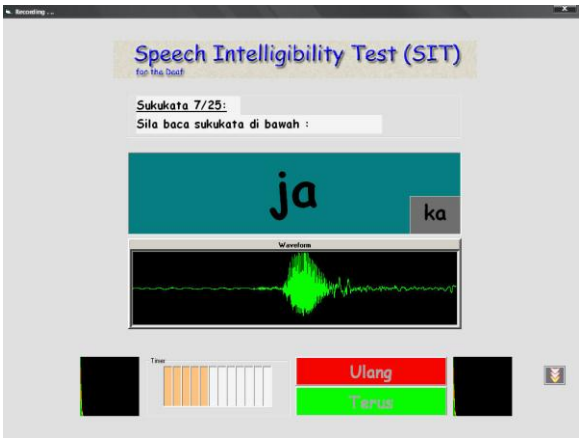

Fig. 5 The recording interface which includes the speech material in large print, 2 seconds timer and the waveform of the speech signals, the red 'repeat' button and the green 'continue' button.

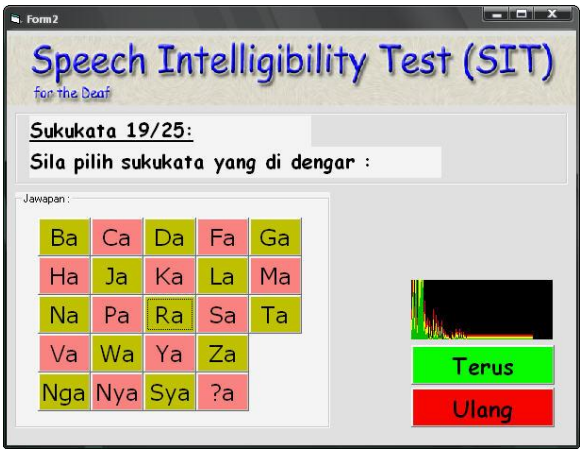

Fig. 6 The assessment interface which includes the answer set of 22 syllables frame and the waveform of the speech signals.

4.0 CONCLUSION

Based on the MSIT procedures, a computer-based MSIT is presented which is believed to be sufficient for recording, managing and assessing deaf children speech. As stated previously, one of the objectives of the study is to prove that the MSIT is valid. It started with the construction of a standard test stimuli based on all Malay phonemes focusing on just the consonants. The standardized test method focused on how the test was planned, administered and scored. Finally, the validity and reliability of the experiments were confirmed using analysis of the results.

The first comparison was on the intelligibility rating by the teachers of the deaf and speech therapists with the MSIT score rating. It was shown that 95% of the intelligibility rating using MSIT subscribe to the intelligibility rating of the experts. The result of Levene's Test for Equality of

Variances implied that there is evidence, at the 5% level, to suggest that there is no difference in test scores between the two groups of human assessors; the speech therapists and the naïve listeners. Thus, the analyses support the claim that the MSIT is valid and reliable to check speech intelligibility of deaf Malaysian children and therefore the system is practical to be used for deaf Malaysian children training and intervention programme.

The successful development of the MSIT system serves several purposes: (a) it will be one of the first methods employed to objectively measure speech intelligibility of deaf Malaysian children, and (b) it will contribute to better assessment and management of intervention programme for deaf Malaysian children.

5.0 FUTURE WORK

In future work, methods for computer's speech recognition should be explored. Computer softwares have been developed to recognize spoken words and even been used as dictating machine. There are various technologies behind these machines and some of them should be explored to be used as MSIT speech recognition engine. Hopefully, human-based MSIT tested in this paper can be transformed into commercial computer-based MSIT with speech recognition for a real practical application on monitoring deaf children training and intervention programme.

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