COMPARISON OF NOISE REDUCTION IN DIFFERENT HEARING AIDS USING MALAY-HEARING-IN-NOISE-TEST

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List of Symbols and Abbreviations

>	Greater than
<	Less than
ANL	Acceptable Noise Level
BTE	Behind the ear
dB	Decibel
dBHL	Decibel Hearing Level
dBA	A-weighted decibel
HA	Hearing aid
Hz	Hertz
HL	Hearing Loss
HINT	Hearing-in-Noise Test
MyHINT	Malay- Hearing-in-Noise-Test
PTA	Pure Tone Audiometry
REM	Real Ear Measurement
SD	Standard Deviation
SNHL	Sensorineural Hearing Loss
SNR	Signal-to-Noise Ratio
SRT	Speech Reception Threshold

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ABSTRAK

Kajian ini dijalankan untuk menentukan dan membandingkan keputusan ujian *Malay-Hearing-In-Noise* (MyHINT) dengan fungsi pengurangan bunyi bising dalam dua alat bantu pendengaran yang berbeza. Pengurangan bunyi bising adalah satu teknologi dalam alat bantu pendengaran yang membantu menguatkan bunyi-bunyi bermakna seperti pertuturan di samping mengurangkan kesan bunyi bising di persekitaran. Subjek bagi kajian ini terdiri daripada sepuluh peserta daripada Klinik Audiologi, Hospital USM dan Klinik Audiology PPSK, USM dalam kalangan orang dewasa berumur dalam 18 tahun ke atas dengan tahap pendengaran ringan hingga ke teruk jenis kekal di kedua-dua belah telinga dan telah memenuhi syarat ditetapkan dalam kajian ini. Subjek telah dipakaikan dengan dua alat bantu pendengaran yang telah diaktifkan dalam dua kondisi ujian yang berbeza iaitu apabila pengurangan bunyi bising dibuka dan ditutup. MyHINT terdiri daripada 12 senarai ayat pendek dan setiap senarai mengandungi 20 jumlah ayat. Hasil kajian ini menunjukkan tiada perbezaan ($p > 0.05$) dalam pengurangan bunyi bising bagi dua alat bantu pendengaran yang berbeza apabila menggunakan MyHINT dengan kehadiran bunyi bising. Markah dalam keputusan MyHINT adalah lebih baik apabila pengurangan bunyi bising ditutup, jadi ia tidak boleh dijadikan sebagai rujukan sama ada ujian ini sesuai untuk melihat kebaikan alat dalam bunyi bising. Namun begitu, pengurangan bunyi bising masih boleh memberi kebaikan walaupun kesannya tidak dapat dilihat dengan ketara dalam semua keputusan subjek.

ABSTRACT

This was a study to determine and compare the Malay-Hearing-In-Noise (MyHINT) scores of noise reduction function in different hearing aids. Noise reduction was a technology in hearing aids that help to amplify meaningful sounds such as speech while reducing the effect of background noise. Ten adult subjects from Audiology Clinic, Hospital USM and Audiology Laboratory, PPSK USM age more than 18 years old with mild to severe sensorineural hearing loss that fulfilled the inclusion criteria were included in this study. Subjects were tested using two different hearing aids with the noise reduction was activated and deactivated in two different test condition. The MyHINT consisted 12 list of short sentences and each lists contain 20 sentences. The stimuli were delivered through speaker and subjects were required to repeat the sentences that they heard with the hearing aid on. The finding from this study showed that there was no significant difference ($p>0.05$) in noise reduction in different hearing aids when using MyHINT in the presence of background noise. Surprisingly, the scores for MyHINT was better when the noise reduction was switched off, hence it cannot conclude whether this test was suitable to be used as a tool to determine the benefit of noise reduction in clinical setting. Whereas, the findings from this study also indicated that noise reduction did provide some benefits to HA wearer even though the advantages of noise reduction may not significantly be seen in all subject scores.

CHAPTER 1

Introduction

1.1 Background of Study

Hearing loss can affect all age groups from newborn until elderly and can give an impact on the speech and language causing social and vocational problems for adults. According to World Health Organization (2015), in the world population, over 5 % which is about 360 million people all around the wolrd has disabling hearing loss. Awareness of symptoms, signs and rehabilitative measures will lead to early identification and treatment for hearing loss (John et. al, 2013). A person who is not able to hear as well as normal hearing people with hearing thresholds of 20 dB or better in both ears is said to have hearing loss. Hearing loss may be mild, moderate, severe or profound (World Health Organization, 2015). Hearing sensitivity loss is usually caused by an abnormal reduction of the sound that is delivered to brain by a disorder ear. In contrast, sounds must be of a higher intensity than normal to be perceived. Type of hearing loss is related to the site of the disorder within the auditory system and degree of loss is related to the extent that the disorder is infringing on normal function. This reduction of sound results from various factors that affect the outer, middle and inner ear (Gelfand, 2009).

The type of loss is characterized into three types which are conductive hearing loss, sensorineural hearing loss and mixed hearing loss. Conductive hearing loss has little or no impact on supra threshold hearing. It means that when the sound has a sufficient intensity, the ear will act as normally it always do at supra threshold intensities. Moreover, the perception of loudness, ability to discriminate loudness and the changes in pitch along with the speech-recognition ability are normal as we increase the intensity of signal. Sensorineural hearing loss can be any shape or degree but the most common configurations have thresholds that get worse as frequency increases. In short, sensorineural impairments involve a greater loss of hearing sensitivity at higher frequencies than at lower frequencies (Gelfand, 2009)

The complexity of sensorineural hearing loss is greater because of it effects on frequency resolution and dynamic range. People with sensorineural hearing impairment also has more difficulty than normal hearing people in listening in background noise and understanding speech .Most patients with sensorineural hearing loss complain that they can hear speech, but it is unclear or hard to understand and become worse in noise (Gelfand, 2009).There are some factors that contribute to these problems including reduced in audibility, reduced frequency selectivity, loudness recruitment and the regions in cochlea that has no surviving inner hair cells or dead region. Furthermore, the speech reception threshold in noise is also higher in sensorineural hearing loss patient than normal hearing people (Moore, 2003). People with cochlear loss also is less able to take advantage of the temporal and spectral dips. According to Moore (2003), cochlear loss patient also has less ability to determine the spectral shapes of speech and has difficulty to separate components of speech in background noise.

Nowadays, modern hearing aids have some advanced features as a standard fitting option and one of the features is noise reduction. The primary goal of having a noise reduction is to reduce amplification in specific bands when a background noise is detected (Magnusson et al, 2013).

The other goal of implementing noise reduction is to reduce the hearing aid gain for background noise while giving a limiting effects on speech signals. According to Mueller et. al (2006), this processing can improve ease of listening, listening comfort, sound quality and speech understanding in noise. In addition, the hearing aids will also determine if signals are speech-like or noise-like and make it owns adjustments in output of specific frequency.

Speech tests such as Hearing-In-Noise Test (HINT) is used to predict the difficulties that people who wear hearing aids will have in certain environment. Speech tests in noise condition are developed to simulate the real-life situations experience by patients (Mondelli et. al, 2015). The effects of sensorineural hearing loss will result in poor speech recognition performance in quiet on how these individuals will perform in the presence of noise. A person who has a sensorineural hearing loss also requires greater signal-to-noise-ratio (SNR) about 10 dB to 15 dB better than normal person (Magnusson et.al, 2013).

In Malaysia, several speech tests have been adapted into Malay for the use of local Malay population. One of the test is Malay-Hearing-in-Noise-Test (MyHINT) which has been developed by Quar et al. (2008). It consists of 12 lists of short sentences and each of the lists contains 20 sentences. Each sentence is constructed with three to five words. Furthermore, in difficult listening situation, theoretically if the characteristics of speech and noise are known, noise reduction certainly have the potential to improve speech understanding in background noise (Mueller, Weber and Hornsby, 2006).

1.2 Problem Statement

The most common complaint of hearing loss patient is to hear speech in quiet and it will become worsen with the presence of background noise. Nowadays, advanced hearing aids may work well in enhancing speech arriving from front by increasing the amplification in channels that carry important speech so that speech is more pronounced than the noise. However, understanding speech in noise is still very difficult even with the most advanced technology. Hence, the speech test has been developed to identify the aspects of functional hearing on how speech is perceived in environmental sounds.

Bentler et al. (2008) reported there is no publish reports to date of any of the processing based of noise reduction providing improvements in speech perception in noise. Unfortunately, speech test is not widely used in in Malaysia. This is maybe due to less exposure about speech test and it is rarely practice here. Even though the Malay version of HINT test has been validated, there is still less research about it's effectiveness in certain new technologies in hearing aids such as noise reduction. This study aims to compare the MyHINT outcome of noise reduction in different hearing aids. In other words, this study aims to determine the performance of different hearing aids with noise reduction. The outcome of this study is from MyHINT scores itself. The result from this research can be used as a reference for others about how the noise reduction differ in different hearing aids.

1.3 Objective of Study

1.3.1 General objective

To compare MYHINT scores of noise reduction in different hearing aids.

1.3.2 Specific objective

1.3.2.1 To determine MyHINT scores of noise reduction in low-end hearing aids.

1.3.2.2 To determine MyHINT scores of noise reduction in high-end hearing aids.

1.3.2.3 To compare MyHINT scores of noise reduction in low-end and high end hearing aids.

1.4 Research Questions

1.4.1 What is the MyHINT scores of noise reduction in low-end hearing aids?

1.4.2 What is the MyHINT scores of noise reduction in high-end hearing aids?

1.4.3 Will there be any differences of the MyHINT scores of noise reduction in low- end and high-end hearing aids?

1.5 Hypothesis of Study

- **Hypothesis 1**

- Null Hypothesis, Ho: There is no significant difference in MyHINT scores of noise reduction in low-end hearing aids.
- Alternate Hypothesis, Ha: There is a significant difference in MyHINT scores of noise reduction in low-end hearing aids.

- **Hypothesis 2**

- Null hypothesis, Ho: There is no significant difference in MyHINT scores of noise reduction in high-end hearing aids.
- Alternate Hypothesis, Ha: There is a significant difference in MyHINT scores of noise reduction in high-end hearing aids.

- **Hypothesis 3**

- Null hypothesis, Ho: There is no significant difference in MyHINT scores of noise reduction between low-end and high-end hearing aids.
- Alternate hypothesis, Ha: There is a significant difference in MyHINT scores of noise reduction between low-end and high-end hearing aids.

CHAPTER 2

Literature Review

2.1 Sensorineural Hearing Loss

Sensorineural hearing loss (SNHL) is the most common type of hearing loss where the term 'sensorineural' is used to indicate either a cochlear or an eight nerve lesion. The diagnosis of the loss is made through audiometry, which shows no significant air-bone gap (American Hearing Research Foundation,2015). A sensorineural hearing impairment is present if the bone- conduction thresholds are outside of the normal limits, that is greater than 15 dBHL, no significant air bone gaps are present and the air conduction are outside of the normal limits that is greater than 20 dBHL. Thus, a sensorineural hearing impairment is characterized by poor bone-conduction thresholds, showing a problem in the sensorineural mechanism, and poor air conduction threshold (Silman & Silverman,1997).

SNHL results from disorders of the cochlea, eight cranial nerve, or cochlear nuclei. Generally, sensorineural hearing impairment is irreversible. In contrast to conductive hearing impairment, sensorineural hearing impairment cannot be alleviated surgically or by medical intervention except some cases of Meniere's disease, sudden hearing impairment associated with interruption of cochlear blood supply, or perilymphatic fistula. Generally, sensorineural loss is managed through aural rehabilitation or habilitation including amplification such as hearing aids (Silman & Silverman, 1997).

Configuration of hearing loss is an important aspect to consider as it provides clues regarding hearing disorder. Speech understanding usually affects the abilities for patient with a high-frequency SNHL to have difficulty discriminating high-frequency phonemes. The average speech spectrum on the audiogram may help in knowing how well the patient is receiving average conversational speech and how patient is discriminating various speech sounds. It is also a major consideration in selection of amplification, such as HAs or hearing assistive technology (Valente, 2009).

Many sensorineural losses are thought to have a sloping configuration in which hearing is better in the lower frequencies and poorer in higher frequencies. Most of them will complain that although they know someone is talking, they cannot understand the words because it is hard to differentiate between consonant (Paul & Whitelaw, 2010). High frequency hearing losses are involved with damage toward base of cochlea. The damage in cochlea may extend upward toward the apex and cause hearing loss in lower frequencies (Gelfand, 2009).

People with SNHL generally suffer from a reduced ability to understand speech in complex acoustic listening situations, particularly when background noise is present. In addition to the loss of audibility, a mixture of suprathreshold processing deficits is possibly involved, like altered basilar membrane compression and related changes, as well as reduced ability of temporal coding. In general, the sensitivity loss which limits the audibility of soft sounds is accompanied by growth of loudness level. It is significantly conditioned by loss or dysfunction of outer hair cells which act as biological motors to amplify smaller motions of basilar membrane to perceive sound (Kortlang, Mauermann & Ewert, 2015).

In addition, even if audibility is of less concern because sound levels are well above threshold, or because amplification and compression are applied in hearing aid, suprathreshold deficit can still persist. This explain why many aided hearing-impaired listeners still have problems in complex listening situations including multiple talkers, reverberation or background noise (Kortlang, Mauermann & Ewert, 2015).

2.2 Effects of degree and configuration of hearing loss on bilateral speech understanding

Listeners with bilateral hearing loss have advantages to a binaural hearing aid fitting over monaural aid fitting. In addition, advancing in age causes some changes in the central auditory system. Typically, binaural amplification is preferred in quiet listening environments if compared to monaural amplification (Carter, Noe & Wilson, 2001). These include elimination of the head shadow effect, binaural summation, binaural squelch and improved sound localization. Fitting a HA is to restore audibility to portions of speech that is due to hearing loss, would otherwise can be inaudible .However, sensorineural hearing loss patient has limited ability to make use of information in amplified speech particularly high-frequency components of speech (Vickers, Moore & Baer, 2001).This is due to limited benefit that is related to the degree of high-frequency hearing loss specifically at degree of high-frequency (>3000-4000Hz) with hearing loss that exceeds 55-80 dBHL will benefit from amplification of speech components within this high-frequency region (Ching, Dillon, Katsch & Byme, 2001).

In contrast, for lesser degrees of hearing loss especially hearing losses in lower frequency regions, improving audibility by amplification generally improves speech understanding (Hornsby & Ricketts, 2003). Limited benefit from high-frequency information is based on results from individuals with sloping high-frequency hearing loss. The presence of moderate to severe SNHL, regardless of the frequency, often results in poorer than predicted speech understanding. Moreover, it is difficult to separate the degradation in understanding due to hearing loss in general from degradation due to hearing loss at high frequencies. In addition, to achieve adequate audibility, individuals with moderate or greater hearing losses are forced to listen to speech at higher levels. In general, as degree of hearing loss increased, performance will decrease (Ching, Dillon, Katsch & Byrne, 2001).

Based on the study conducted by Ng, Rudner and Lunner (2014), they found that familiarization to the HA amplification and settings over time is needed to support the hypothesis because a new user to HA will have a greater need for explicit cognitive processing and storage capacity. As the user becomes familiarized to HA, the explicit processing is reduced. For instance, an adult with a moderate hearing loss without the use of amplification, they will miss half of the content in speech with a hearing loss of 40 dBHL to 50 dBHL even if they are in quiet listening conditions. The social effect includes no longer being able to enjoy going to restaurants, theater, and others for example when they involve in a noisy group setting that cause them a high degree of difficulty (Welling and Ukstins,2013). The researchers also reported that hearing loss that falls within moderately severe hearing loss can be extremely handicapping as the individual with a loss at 55 dBHL can miss out total average level conversation.

In a following study done by Jose, Campos and Mondelli (2011) among adults with moderate to profound hearing loss bilaterally, most of them reported that by using an amplification really helps them much in the situations which they have hearing difficulties and improving in the amplification of speech sounds. However, a study done by Wilson & McArdle (2005) showed that even though the presentation levels of speech signals are raised, the speech recognition performance decreased in aided condition for individuals with PTAs of >40 dBHL. The researchers had studied that the relationship between hearing loss and speech-recognition performance in noise was strengthened with the inclusion of 4,000 Hz in the PTA, whereby speech-recognition performance in noise depends solely on the audibility of high frequency.

2.3 Directionality in bilateral fittings

Nowadays, with the advance in technology, the directional microphones system provides a static answer pattern which focus on subject's front direction. It is based on the supposition the speaker will be in front of the listener and the noise background will come from the sides or behind. However, some studies reveal that the voice signal does not come from the listener's front (Mazzochi & Aita, 2013). Directionality occurs because the head and pinna attenuate the sound when they come between the source and microphone, boosting the sound when the microphone is positioned between them and the source. These boosting and attenuating effects of head diffraction increase in magnitude as frequency (Dillon, 2012).

The intelligibility of speech in noise can be improve with the use of directional processing which preserves sound arriving from the front of the hearing aid wearer but attenuates sound arriving from the side and from behind the wearer. In addition, the speech that a hearing aid user wants to hear is usually is in front of them and interfering noise is all around or behind the user. The directional-dependent gain can improve the overall SNR even the noise has the same spectral content as the signal or occur at the same time (Edwards, 2000). As the target speech is directly in front of the listener, the improvement to SNR provided by a specific directional pattern depends on the direction of the noise sources.

According to Edwards (2000), if the noise only arrives from the same direction as the target speech, then there is no improvement to the SNR with directionality. However, interfering sound sources in noisy environments can also arrive at the listener from all directions, particularly in reverberant environments where the hyper cardioid provides the greatest SNR improvement. However, in poorest SNR, directional microphones may be important for greater benefit. Directional microphones are more recommended to use in the presence of competing noise, especially in higher noisy situations. Even though the speech-recognition ability is not significantly improved with the use of directional microphones in many typical SNR environment, there may be other subjective benefits to directionality such as reduced listening effort, distraction, or annoyance that listeners respond more to (Galster & Stevens, 2013).

Furthermore, Gnewikow, Ricketts, Bratt, & Mutchler (2009) stated that the SNR is improved by providing more gain for sounds arriving from frontal azimuths than those from rear azimuths. Moreover, hearing aids users will have better understanding and improve speech understanding with their aids than without one. The microphone is more sensitive to the sounds coming from the front of listener than sounds coming from other angles of incidence. Listener may become unable to detect signals from the complex acoustic environment and unable to use naturally occurring intensity cues to help in localization (Ruscetta et. al, 2007).

In contrast, if the HA does not accurately classify the type of listening environment, the effect of the directional microphone could be minimized (Bentler & Mueller, 2011). Many studies had been done to evaluate the directionality on speech recognition outcomes. Research done by Nordrum, Erler, Garstecki & Dhar (2006) found that five out of thirteen participants were consistent while performing best in the directional microphone condition with two hearing aids and best with the addition of noise reduction function. However, the number of individuals performing best with directional microphone alone or together with noise reduction function was approximately equal when tested with HINT. To support this, the use of microphones from two hearing aids fit binaurally and communicating wirelessly with each other has the potential to improve directional effects (Beck & Nilsson, 2013). Hearing aids with directionality must be position in relative to competing noise sources and face the speech source that need to be attended (Galster & Stevens, 2013).

Another study done by Walden et. al (2000) by recruiting 40 hearing-impaired patients with sloping moderate SNHL bilateral showed that mean performance differences were highly significant for directional microhphone if compared to omnidirectional systems in laboratory measures of speech recognition. However, not all of the findings showed positive outcome of directional microphone. In the field ratings, the results observed are not consistent with laboratory settings. No relationship was found in the laboratory performance of speech perception in noise to field ratings of speech understanding in noise.

Several test environment factors that can impact the benefit of directional microphone include the number or placement of competing noise sources, reverberation and distance of listener to the source of speech. Significant directional benefit is present in the reverberant environment; however, the amount of directional benefit is independent of the origination angle of the competing noise source. Besides, the number and placement of competing noise sources will affect directional benefits by the amount of configuration of competing noise sources as it will impact the benefit from HA if compared to a single noise source (Ricketts, Lindly & Henry, 2001).

2.4 Noise reduction in hearing aid

To begin with, hearing aids allow for some degree of signal processing reducing the effects of noise. Development of digital HA has opened up new possibilities to the use of advanced signal processing techniques for noise reduction due to damaging effects of background noise in speech intelligibility for people with hearing loss. Most hearing aids users have SNHL. Walden et. al (2000) assessed speech understanding and sound comfort for directional microphone with and without noise reduction. Their research found significantly better sound comfort ratings when noise reduction is used together with directional microphone than without one.

However, most hearing aids users have sensorineural hearing loss. A problem of providing amplification for this type of hearing loss is that the dynamic range of hearing is reduced. Dynamic range of hearing is the level difference between loudness discomfort level and threshold of audibility (Dillon,2012). Hearing-impaired people typically require a SNR that is at least 3 to 6 dB higher to achieve the same degree of speech intelligibility (Jinqiu et. al, 2015).

Besides, the threshold of hearing is also raised as a result of the hearing loss, but the threshold of loudness discomfort remains the same or even lower than normal hearing. As a consequence, the dynamic range of hearing is usually much narrower in high frequencies (Jinqiu et. al, 2015). A reduced dynamic range may put even high level input sounds near a user's threshold. An aggrasive noise reduction setting for instance one with high maximum attenuation may yield usable performance for a user with a mild hearing loss while making speech energy inaudible for someone with a moderate to severe loss (Stelmachowicz et. al, 2010). Noise reduction relies on the differences of physical characteristics of a signal to distinguish speech from noise by analyzing the intensity of distribution of the signal. It assumes a greater variability in the intensity of speech when compared to noise. When the signal in any frequency channel is detected as noise, gain is reduced for that channel proportionately to the level of noise (Kuk, Ludvigsen & Muller, 2002). The noise reduction maybe effective in improving speech perception in noise when the speech and noise sources are not spatially separated.

There are several type of noise reduction algortihms that are available invented to provide satisfaction to the listener. For instance, previously, Voice IQ from Starkey Hearing

Technologies was implemented to resemble a noise reduction technique called spectral subtraction. By using this approach, the hearing aid is able to maintain separate estimates of speech and noise signals processed by the hearing aid. Furthermore, the noise estimate is used to inform the algorithm behavior which attempts to subtract the estimate noise from the overall imput of hearing aid. (Galster, 2014). Research that was conducted by Starkey Hearing Foundation and in collaboration with University of California on clinical outcomes of Voice IQ confirmed a similar benefit where subjects demonstrated robust audibility of soft speech sounds and improvement in sound quality. However, it only has provided some initial insights about the benefits of this algorithm. In order for a noise reduction to be functional, it must be able to increase intelligibility and at the same time improved the perceived quality.

Bentler (2005) conducted a study about the subjective benefit of noise reduction in real world but there is little evidence supporting improved speech understanding or listening comfort. Further study by Ricketts and Hornsby (2005) showed that their participants preferred the noise reduction to be activated compared to when the noise reduction is off when listening speech in noise. However, the preference is present for both omnidirectional and directional microphones hence these participants did not demonstrate an intelligibility improvement in the same noise if the noise reduction is on suggesting that the preference was base more on perceptual rather than speech understanding. To support this, a study conducted by Mueller, Weber and Hornsby (2006), with adult participants age from 23 to 76 years old who had mild to moderate hearing loss showed that when the noise reduction is activated, there is a positive improvement but it is not surprising that the speech intelligibility did not improve. Although noise reduction might reduce the noise in gaps between the words and syllables of the sentence, SNR of the remaining speech and noise did not change much. He also questioned that whether audiometric or HA factors might affect the result but the data analysis showed otherwise. Previous research has also suggested that speech understanding will not improve even the noise reduction is on.

Furthermore, according to Bentler, Wu, Kettel and Hurtig (2006), there had been no publish reports to-date about noise reduction providing improvements in speech presence in noise, but slowly the data starts to emerge relative to benefits for the current noise reduction algorithms but still more research need to be done in different HAs.

2.4.1 Importance of reducing the effect of noise in adults

Difficulty in understanding speech in noise is the most common complaints of hearing aid users. When the ability to understand speech in noise is expressed in a SNR for understanding half of speech, the SNR of people with hearing loss may be as much as 30 dB higher than people with normal hearing. When a background noise is present, the speech needs to be as much as 30 dB higher for people with hearing loss to achieve same level of understanding as people with normal hearing. The exact amount of SNR loss depends on the degree and type of hearing loss, speech materials and temporal characteristics of background noise (Chung, 2004). Specifically, a successful amplification use is concluded base on the variable SNRs within particular environments that determine an individual's successfulness. Individual with hearing loss that could understand speech at lower SNRs are likely to be more successful with hearing aids than the one that needs higher SNRs. Therefore, bilateral digital technology with noise reductions can enhance the intended speech to have a successful interaction (Ng, Lunner and Rudner,2014),

However, when listening conditions are challenging, a mismatch situation may arise where an explicit processing is needed to match the degraded input with representations in the long term memory store. Rudner, Ronnberg and Lunner (2011) reported that processing the speech signal may have a stronger impact when the hearing aid setting is new than after familiarization. It is observed in a new user to hearing aid where the incoming processed signal might be distorted by cochlear damage as it may not have matched with the established phonological representations. When the user is accustomed to the HA amplification and setting, the degree of mismatch may decrease. In a following study done by Ng, Lunner and Rudner (2014) stated that the efficiency of speech processing is dependent on working memory capacity. As a consequence of cochlear damage, individuals with cochlear damage or sensorineural impairment are exposed to a distorted auditory input. The effects of aging on the human auditory system will cause the sensitivity to decline, range is reduced, speech understanding in noise is compromised, and cognitive processing to become slower. Schenider et. al (2010) reported that an effective communication in complex listening environments needs peripheral auditory systems and cognitive to function well. If the process is disrupted at one point, the ability to understand speech breaks down.

Furthermore, listening in noise which is common in real life will make speech perception more challenging. When the speech signal is masked by noise, a cross condition may arise. Iindividual with hearing impairment will have a disportionate difficulty listening in noise causing them to experience more complicated processing. Challenge in listening caused by processing speech signal may have stronger impact when the hearing aid setting is new than after familiarization. New user to hearing aid amplification will experience distorted incoming processed signal due to cochlear damage that is not readily matched with the long-term memory (Ng, Lutner & Meller, 2014).

2. 5 Effect of speech perception in presence of noise

The speech recognition depends on the integrity of the peripheral and central hearing system with the combination of the traits like the intensity, the acoustic signal length, the phoneme frequency track, the prosody, the familiarity with the vocabulary and the linguistics context. However, in daily basis, with the presence of voice and background noise at the same time, it requires the listener to make use of all the traits available in order to be able to comprehend the message. Someone with a hearing loss will cause these traits to be affected. Therefore, the difficulty of understanding speech in background noise is perceived as one of the main hearing disabilities (Mazzochi & Aita, 2013). Patients with HL complain of inability to understand speech in presence of background noise, especially background noise composed of multiple speech sources. Patient's complaints of difficulty understanding speech in background noise are a characteristic manifestation of the distortion component of hearing loss. Communication handicap imposed by SNHL was not only characterized by hearing loss in the threshold for speech in quiet but also in the masking efficiency of competing speech and other background sounds that restrict the patient when he is in complex listening environments for instance in background noise (Wilson & McArdle, 2005).

Audibility is crucial for speech intelligibility as if a part of speech spectrum is below absolute threshold or is masked by background sound, and then information is lost. The frequency range from about 200 to 9000 Hz is the range most important for intelligibility. Each band represents the overall intelligibility. Adding a noise background to speech fills in spaces between the spectral peaks and thus reduces their prominence, exacerbating the problem of perceiving them for people with broadened auditory filters (Moore, 2003).

Patient with SNHL have different etiologies and pathologies which can affect frequency processing even at the level of the cochlea (Xu, Zhou, Brashears & Rife, 2008).

Any decline in speech recognition that occurs as a result of a naturally degraded speech signal may give an effect in communication. Adults commonly report that the speech of young people is difficult to understand. Although this observation clearly results from contextual as well as linguistic factors, it is possible that the faster speech rate commonly observed in younger speakers (Harnsberger et. al, 2008). In the process of understanding speech or spoken language, listeners must attend to the auditory stimulus, perform acoustic analysis, map the stimulus to phonemic categories, store the information in memory for further processing and finally map phonemes to a meaning. Every spoken language processing does not always occur in quiet environment but there will be some level of noise that also interferes as background. Noise can be defined as unwanted or annoying auditory input. The ability to discriminate speech sounds decreases with increasing noise levels as prolong exposure to noise can affect the brain organization of speech processing and attention control to focus on speech (Manan, Yusoff, Franz & Mukari, 2013).

2.6 Importance of Speech Test

Speech is the auditory stimulus through which we communicate. Speech thresholds are used as a mean to cross-check the validity of pure tone thresholds. Furthermore, speech threshold is also one of the basic test for hearing and sometimes it is also used to determine the level of suprathreshold speech recognition testing but it is lack in validity (Schoepflin, 2012). Numerous measures of speech intelligibility, including word recognition, sentence length, and speech-in-noise tests are usually done for pre-fitting selection and hearing aid fitting verification protocols. Most audiologists believe speech intelligibility testing is an important component of the hearing aid selection and fitting protocol. It is also one of the important clinical procedures that can predict the benefit in real-world listening situations (Taylor, 2007).

In addition, for a subject with hearing loss, even though one who have a slightly one may be having problems when all the traits that come from the environment became fundamental for the message recognition due to a problem in hearing. This is the reason why difficulty understanding speech with background noise is perceived as one of the main hearing disabilities that can lead to many cases affecting their life quality (Mazzochi & Aita, 2013). Speech tests can address directly the most common complaint that patients have which is the inability to hear well in background noise. As this is the most common complaints that vary in all age ranges, it can provide some valuable information about the most appropriate amplification strategy. Furthermore, the results from speech tests can also identify if someone needs directional microphones, noise reduction programs or whether they don't need these if they are doing well .

However, according to Cord, Leek and Walden (2000) individual differences in susceptibility to noise interference may be a primary factor in explaining why a hearing-impaired individuals receive different benefit from hearing aids. Listeners with SNHL often require a more favorable signal-to-noise ratio (SNR) than normal hearing person to obtain the same level of speech understanding. Secondly, this is also not due to reduce hearing sensitivity but listeners with the same degrees and configuration of hearing loss may differ in ability to understand speech. There are variety of different speech tests that are widely use and one of the hearing-in-noise-test (HINT). It is a digitally recorded sentence lists created by Nilsson et.al in 1994. A Malay HINT has been established by Quar et.al in 2008. A quiet SRT is established when the first sentence of a list is presented repeatedly below the subject threshold with the intensity increasing in 4 dB until the listener can reproduce the complete sentence correctly. Each sentence is presented only once, and a person need to repeat aloud what is been heard. The level of the next sentence is based on the correctness from the response.

Moreover, two previous studies (Nordrum, Erler, Garstecki & Dhar, 2006; Mueller, Weber & Hornsby, 2006) had used HINT as their assessment tools to determine the benefit of noise reduction. Significant difference in two noise reduction conditions were noted in both studies.

A study was done by Cord, Leek and Walden (2000) described how unaided speech recognition ability in noise is related to the perceived hearing aid benefit. It had shown that hearing-impaired individuals demonstrated a greater susceptibility to noise interference would gain less benefit from the use of amplification. A variety of speech tests are used such as the Self-Assessment of Hearing Handicap, Speech Recognition Testing, Monosyllabic Words Test and also Hearing-In-Noise-Test on sixty adults subject with bilateral SNHL. Majority of subjects showed significant benefit from the use of amplification regardless of speech recognition ability in noise. The outcome of this study suggest that hearing aid fitting may not be an indicator to success or failure factors for rehabilitation for people with hearing loss. The results also suggest that the benefit obtain are not just from the hearing aids but also from the rehabilitation program.

CHAPTER 3

Methodology

3.1 Research Design

The research design of this study was a repeated-measure design in which the same subjects were used with every condition required in the research, or repeated measurements were made to each subject. Each subject was measured repeatedly at one point in time.

3.2 Study Location

This study was conducted at Audiology Clinic, Hospital Universiti Sains Malaysia and USM Audiology Clinic, School of Health Sciences, Universiti Sains Malaysia (USM) Health Campus.

3.3 Sample size

Subjects were recruited from Audiology Clinic, Hospital USM and Audiology Laboratory, PPSK USM. The targeted number of subjects were 26. However, only ten subjects agreed to participate in our study.

3.4 Sampling method

The sampling technique used in this study was convenience sampling.

3.5 Participants

The participants were recruited from Audiology Clinic, Hospital Universiti Sains Malaysia (HUSM). Only individual who fulfilled the inclusion criteria was allowed to participate in this study. A flow chart of subject selection was shown in Figure 3.1.

3.5.1 Inclusion criteria

- Adults above 18 years old.
- Individual who was a native Malay language speaker.
- Individual with symmetrical mild to severe hearing loss sensorineural (SNHL) hearing loss bilaterally.
- Individual with post-lingual hearing loss.

3.5.2 Exclusion criteria

- Individual with outer and middle ear diseases.
- Adults with hearing aids usage experience.
- Individual who withdraw from testing during data collection.