2-3-2-1-2

MIRJO VOL. 2, ISSUE. 3, PP 47-54, DIS 2017 eISSN 0127-6271

MALTESAS Multi-Disciplinary Research Journal (MIRJO)

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Loudness Perception Differentiation Using Repeating Sinus Rhythm

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Abstract. During the setting of hearing aid device process, the most comfortable loud (MLC) level is the most difficult level to determine with by existing methods i.e., verbal or behavioral technique. This is because the hearing aid device users should evaluate their own given the volume level. The users might find it confusing as this level is next to uncomfortable loud level (UC). UC level is not considered for the determination of the loudness scaling because in a long period it will damage the user's hearing. The setting process will be more challenging if the user does not have any listening experience such as a child. Thus, the relationship in between the decline of the N100 wave peak and loudness perception is studied to distinguish between the MLC and UC for an objective loudness scaling measurement. As a result, the percentage decrease in N100 peak decreased with increasing volume is observed. From the results, it was found that for the level UC, the percentage decrease in peak N100 does not exceed 1.95% by 3 out of 7 subjects. While MLC showed the percentage decrease in N100 peak higher than UC and lower than the MEDIUM. In conclusion, the loudness perception can be measured by the percentage decrease in peak N100 and this method can be used to adjust the hearing aid device objectively.

Keywords—*N100 reduction; attention deficit; loudness perception*

INTRODUCTION

Determining the most loud but comfortable (MLC) levels is a difficult task during the hearing aid device setting process. This statement is approved by most audiologists [1]. This task becomes increasingly difficult when the hearing aid device becomes more sophisticated so that it can be implanted in the hearing organ. Hence, the demand for its efficiency allows the user to listen more clearly and accurately. Hearing aid devices need to adjust to the lowest and highest level of sound according to individual needs and comforts. 2 levels of the sound volume are the threshold level (TH: the level where the sound began to be heard) and the most powerful but comfortable (MLC: the highest level of sound is most comfortable).

If a hearing aid is custom-fitting beyond the user's MLC level, they may always adjust the sound control to reduce the input signal, so the received sound will not be enough and then the clarity of the conversation will be affected. This was stated by Smoorenburg et. al [2], that is, the level of MLCs is very important to accurately fit because it has a significant impact on the understanding of conversations compared to the level of TH. Additionally, users may be at risk of damage to the hearing system due to the MLC level [3]. Studies have shown that many users of hearing aid devices are dissatisfied with the volume level of their listening tools [4] particularly the level of MLCs.

To date, sound volume scale measurements during hearing aid settings are still subjective in that the hearing aid device receiver should determine the sound volume level verbally after the stimulus is given. This method is not easy to do, especially to determine the level of MLCs when the recipient is unable to provide full cooperation such as children. MLC is a level bordering on a very strong but uncomfortable level (UC). The UC level is a very strong level that must not to be exposed to for a long time. Often MLCs are deliberately reduced their observations because consumers are worried about going beyond the UC level. This results in inadequate volume of noise allowed by the device.

Hence, various efforts have been made to develop the method of determining the MLCs objectively. Brown et al. [5] and Hughes et al. [6] has shown that the correlation between the limits of the electric excellence action capability with TH and MLCs is very effective but not strong. Potts et. al [7] finds that the limit of the telemetry nerve reaction can expect TH and UC contamination on the electrode. However, half of the subjects do not meet the results. Studies are now aiming at the development of objective methods to determine the sound volume, especially to determine the level of MLCs. This study was started by Mariam et. al [8] and Mariam et. al [9] which shows the electroencephalography (EEG) response, which is the recording of electrical activity in the scalp layer is decreasing when the sound intensity is higher. However, the intensity of the sound does not represent the sound volume to a person. This is because everybody has a perception of different sound intensities. Therefore, in this study, the relationship between the sound and the effects of the EEG response decrease is explained to the perception of the noise. Subsequently, this study will also examine the effectiveness of repeating sinus tone to differentiate between the level of MLCs and UC.

METHODOLOGY

Subjects and Experimental Paradigm

10 healthy adults (6 men and 4 women: 20 years old and 4 months old with standard deviation of 1 year and 5 months) participated in this study. Experiments were conducted after the subject was described in the experimental method carefully and signed the truth form. All subjects have no history of hearing problems with hearing levels (below 15 decibels (dB)). Each subject received an audiogram test before and after the experiment to ensure no side effects. The stimulus used is 1000 Hz sine tones over 50 milliseconds. This tone is given repeatedly every 1 second. The stimulus is generated by the computer and is heard on the right ear.

To get the sound level response of MEDIUM, MLC and UC, the subjective measurement was done before the experiment. For that the sinus tone is heard to the subject with a noise intensity of 10 dB up to 90 dB randomly. Subjects are asked to classify the sound volume by indicating Pascoe's sound volume scale as shown in Fig. 1. For EEG recording, stimulus is stimulated to the subject at MEDIUM level, MLCs and UC separately with 3 minutes break between measurements. This test takes about 1 hour including the subject preparation. EEG recording is done in soundproofed rooms. The subject is placed on the recliner chair according to their comfort. The subjects are asked to always feel calm and comfortable with eyes constantly closed and do not perform large moves along the experiments. However, they are not allowed to sleep. For that reason, the subjects are constantly monitored for monitoring the signs of sleep such as snoring or fast eye movements. If, the subject is found sleep, the size reading will be discarded. EEG is recorded using BIOPAC Inc., MP150 EEG 100C and computer software (Acknowledge 4.2). Surface electrodes (Ag / AgCl) are placed to the right of mastoid, vertex and forehead. Impedance is always under 5 kΩ.

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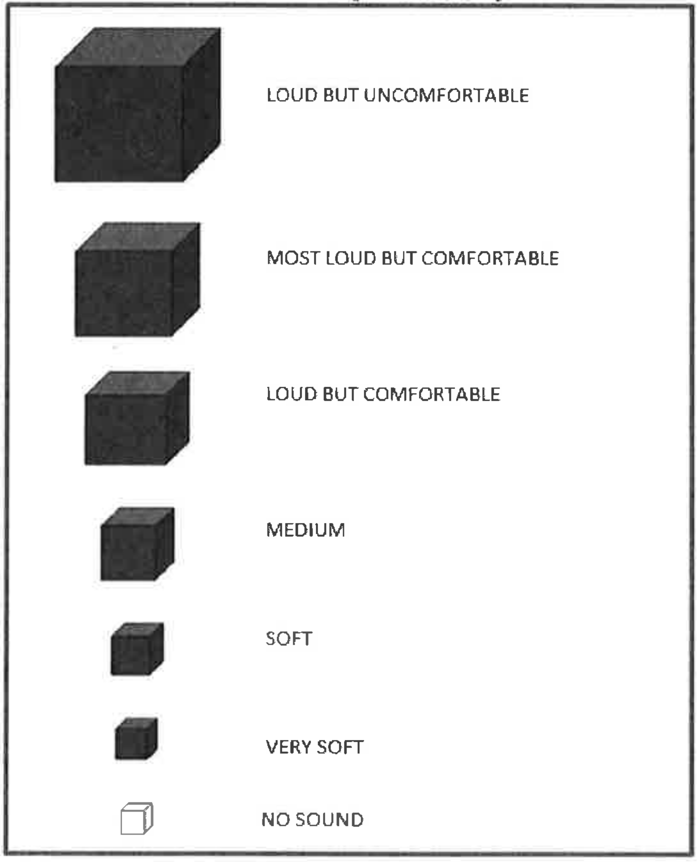

FIGURE 1. Pascoe Loudness Scale

Data Segmentation

Stimulus will be repeated 200 times for each sound volume level. EEG will be cut between 1 to 800 milliseconds after the stimulus. Each piece of this EEG will be referred to as a response along this paper. These reactions will be filtered using a 1-30Hz broadband filter.

RESULTS

To analyze the peak N100 of the recorded reaction, these reactions are the same as shown in Fig. 2. This method is to reduce the signal ratio to noise and thus clearly display the N100 component. Let set A = {xi: i = 1, 2,. . . , N}, that is, N is the number of reactions recorded at one stage of stimulation. To produce a clear N100 peak as shown in FIGURE 2, the reaction of set A will be weighted for every 5 reactions. The average 1 is the average result of set A = {xi: i = 1, 2,. . ., 5), Average 2 is the average result of set A = {xi: i = 6, 7,. . ., 10), and Average 3 is the average result of set A = {xi: i = 11, 12,. . ., 15). Clearly seen the peak of N100 Average 1, Average 2 and Average 3 decreased against stimulation. In this case (subject 1 at a moderate level of stimulation), it is noted that the peak of N100 reactions continues to decrease along the experiments.

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Evaluation is done by differentiating the average of the N100 semi-final peak with semi-final experiments ([B = {Average x_i: i = 1, 2, ..., M / 2}] - [C = {Average x_i: i = M / 2, M / 2 + 1, ..., M}] where M is the sum of the resulting average. Figure 3 up to FIGURE 7 shows the percentage difference of N100 peak for each subject at all stimulation levels. The average subtraction percentage decreased to 7.52% with standard deviation (std) of 6.74 The decrease in the percentage difference was lowered at UC level, with the average deviation of 12.33% with std 2.55 on average. The TABLE 1 shows the results of the Mann-Whitney U-Test statistical test (the effectiveness level of p <0.05), showing the percentage of N100 difference between each subject is not significant even with large standard deviation.

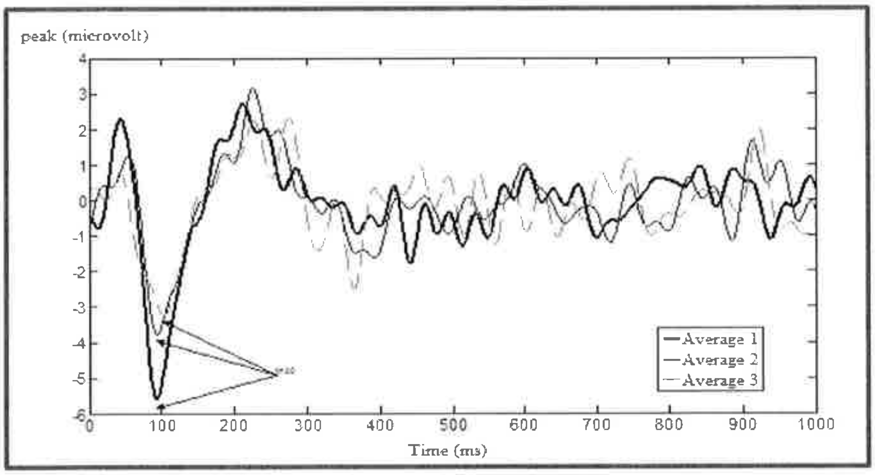

FIGURE 2. The segmented EEG wave will be averaged on every 5 waves. The average 1 is the result of the average reaction of 1 to 5, Average 2 is the average result of the reaction 6 to 10 and Average 3 is the result of the average reaction of 11 to 15. The N100 peaks Average 1 are more negative than Average 2 and 3.

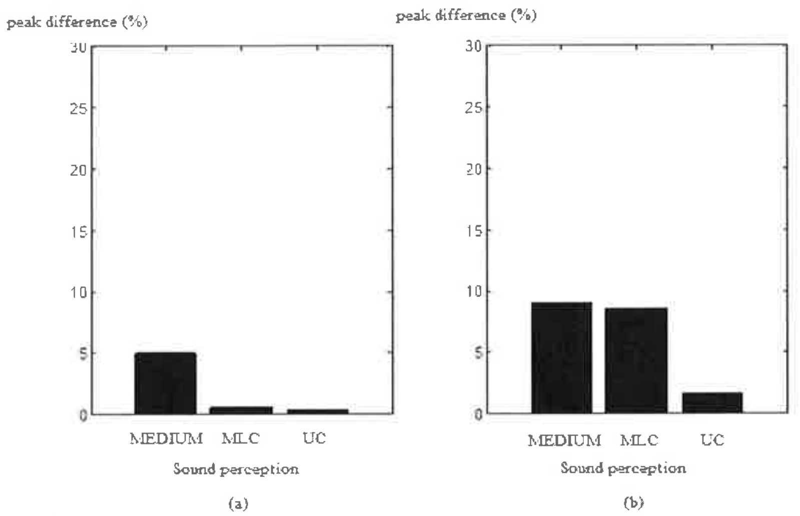

FIGURE 3. Shows the percentage graph of the N100 peak difference to the sound perception of subject 1 (a) and subject 2 (b). It shows that, the N100 peak decrease over increasing of perceived sound.

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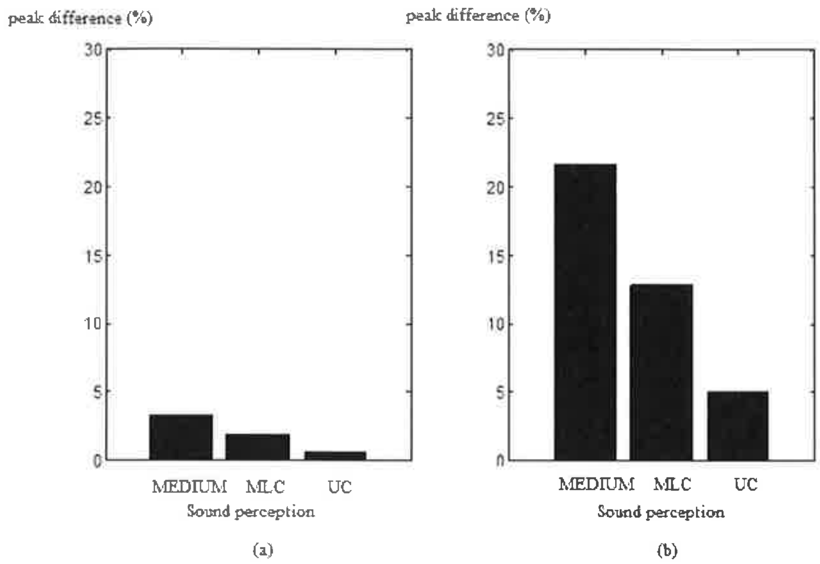

FIGURE 4. Shows the percentage graph of the N100 peak difference to the sound perception of subject 3 (a) and subject 4 (b). Both show similar pattern of declining of N100 peak over increasing of perceived sound.

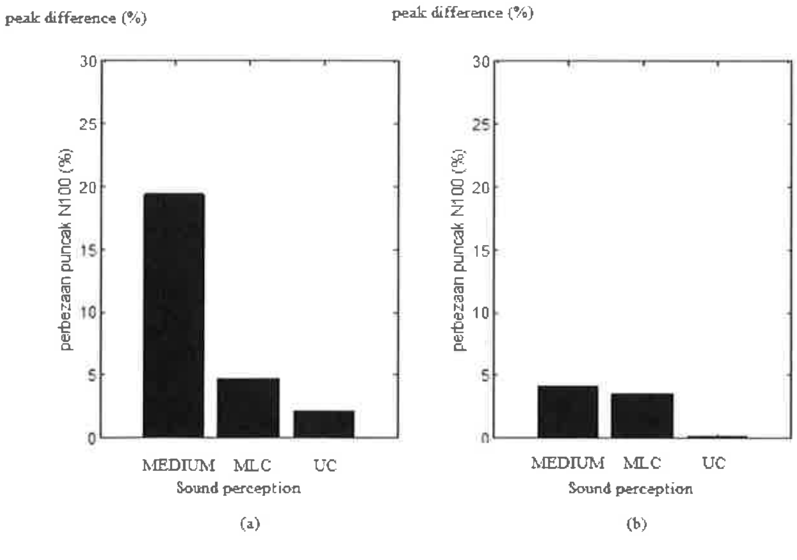

FIGURE 5. Shows the percentage graph of the N100 peak difference to the sound perception of subject 5 (a) and subject 6 (b).

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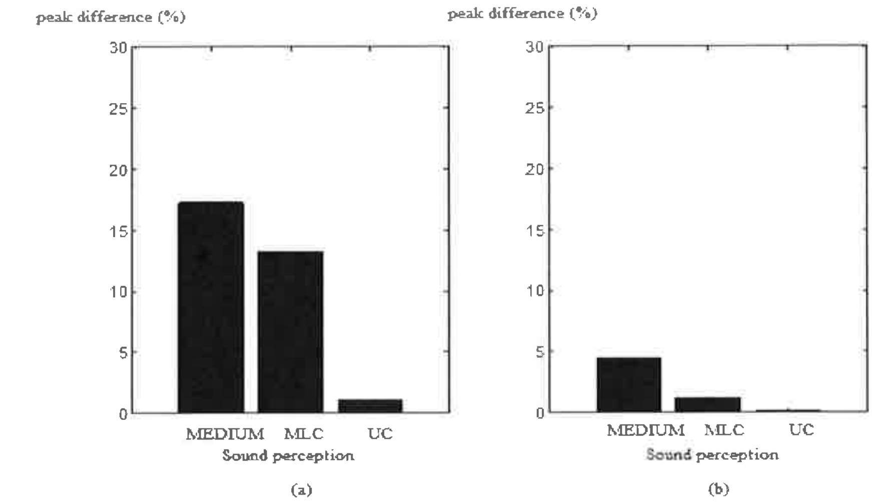

FIGURE 6. Shows the percentage graph of the N100 peak difference to the sound perception of subject 7 (a) and subject 8 (b).

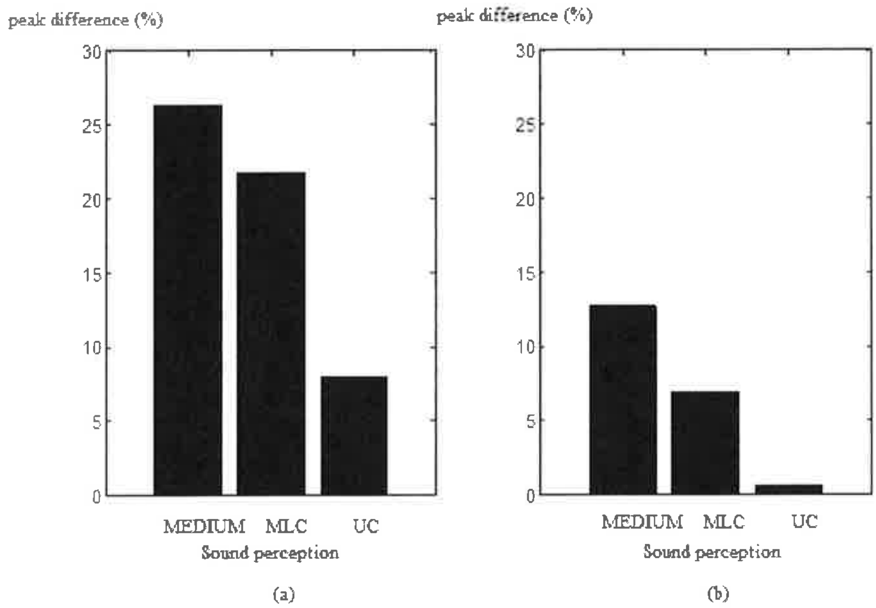

FIGURE 7. Shows the percentage graph of the N100 peak difference to the sound perception of subject 7 (a) and subject 8 (b).

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TABLE 1: Mann-Whitney U-Test p value (level of effectiveness p <0.05) for medium level, MLCs and UC on all subjects

Perception	p-Value
MEDIUM	1
MLC	0.55
UC	0.55

DISCUSSION AND CONCLUSION

In this study, the relationship between the degrees of N100 peak reduction and loud and perceptions was studied. Based on previous studies, continuous stimulation will result in lower N100 peaks [10], [11], and [12]. However, [10] and [8] has shown that high sound intensity fails to show an effective peak decline. However, the intensity of the sound does not symbolize the volume of sound heard by someone. Based on subjective assessment conducted by Mariam et. al [9] found that the level of sound perception among individuals with other individuals is very different. Therefore, in this study, EEG waves are recorded at the level of sound perception, not based on sound intensity. To get accurate and reliable sound response assessments, subjects are chosen among those who have normal hearing.

The main purpose of this study is to distinguish between the level of perception of MLCs and UC. For that reason, three levels of sound perceptions from the sound volume scale table namely MEDIUM, MLC and UC have been studied. MEDIUM levels are used as control readings. Determining the level of UC is very easy because it is an extremely high level and normally rejected for a long time of simulation. However, to determine MLC is very difficult. This is because MLC is often misinterpreted as UC, so the hearing aid device users will lower the sound tuner and cause the adjusted listening level to the device to be inadequate. As discussed in the introductory section, MLCs are important to be precisely determined in order to achieve better development of speaking ability, particularly the recipient of a child's cochlear implant.

Based on the results obtained, MLCs and UC can be distinguished by the proposed method. If the average value of the peak decline is taken as a benchmark for each sound impression, it is found that 7 out of 10 subjects show a decrease in the N100 peak for UC stimulation level not exceeding 1.95%. it may be suggested that when the N100 peak decline does not remain at 1.95% during measurement, it means that the stimulation level has reached UC. However, if viewed individually, 3 out of the 10 subjects have a very high peak drop at MEDIUM level. Hence, it is arguable that the possibilities of these individuals have a high degree of ability to ignore a stimulus and thus result in a drop of over 5% even at the UC level. However, it is still much lower than the MEDIUM level significantly. For the MLC level, if the average score is 7.52% as upper benchmark and 1.95% as lower benchmark, 4 out of 10 may be misinterpreted as MEDIUM and 2 other subjects will be considered as UC. However, individual assessments show that the level of MLCs does not exceed the level of MEDIUM and less than UC significantly (Mann-Whitney U-Tests statistical test (significance level p <0.05)).

From the results obtained, it is still too early to state the percentage of N100 peak drops to determine the level of UC and MLCs precisely because of the small number of samples taken. This percentage drop percentage can be achieved by obtaining large samples in the future. However, a relationship between the N100 peak decline and the sound response was seen in this study. The method proposed in this study can be used as a basis for developing a procedure for the sound level arrangement process for coke implant users and hearing aid devices.

The proposed method also can be used to examine the level of awareness and attention to education and driving safety.

ACKNOWLEDGMENTS

The authors are grateful for financial support received through the FRGS research grant (FRGS /1/2017/TK08/FKEKK-CETRI/F00338) from the Ministry of Higher Education Malaysia. Thank you very much for the support of the students of Universiti Teknikal Malaysia Melaka participating in this study.

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