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COMPARISON OF PSYCHOACOUSTIC MEASURES USING TWO PIECES OF SOFTWARE: PSYCON AND MATLAB'S MAXIMUM LIKELIHOOD PROCEDURE

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

Background: Psychoacoustic abilities play a crucial role in speech perception. Psycon and Matlab's maximum likelihood procedure (MLP) are two commonly used pieces of software to assess psychoacoustic ability. The present work compares a number of psychoacoustic abilities based on Psycon and MLP.

Material and methods: There were 39 participants with normal hearing sensitivity who were enrolled in this study. The psychoacoustic measures assessed were gap detection threshold (GDT), duration discrimination threshold (DDT), difference limen of intensity (DLI), and difference limen of frequency (DLF). These measures were done using both Psycon and MLP, and a comparison was made between the two. An attempt was made to keep the stimuli specifications similar in Psycon and MLP except for the duration of stimuli in GDT.

Results: A Wilcoxon signed-rank test was used to determine the significance of differences between MLP and Psycon. The results showed no significant difference in DLI, DLF, and DDT between MLP and Psycon; however, a significant difference was found in GDT.

Conclusions: It can be concluded that the results of DLI, DLF, and DDT can be generalized between Psycon and MLP. However, further research with a larger sample would strengthen the current study's findings.

Key words: MLP • psychoacoustics • Matlab • Psycon • difference limen

PORÓWNANIE RÓŻNYCH POMIARÓW PSYCHOAKUSTYCZNYCH Z ZASTOSOWANIEM DWÓCH PROGRAMÓW: PSYCON I METODY NAJWIĘKSZEJ WIARYGODNOŚCI W MATLAB

Streszczenie

Wprowadzenie: Zdolności psychoakustyczne odgrywają kluczową rolę w percepcji mowy. Psycon i metoda największej wiarygodności (MLP) to dwa popularne programy wykorzystywane do oceny zdolności psychoakustycznych. Niniejsze badanie porównuje szereg zdolności psychoakustycznych na podstawie Psycon i MLP.

Materiał i metody: W badaniu wzięło udział 39 uczestników z normalną czułością słuchu. Ocenie poddano następujące pomiary psychoakustyczne: test rozdzielczości słuchowej układu słuchowego (GDT), próg rozpoznawania trwania (DDT), próg różnicy natężenia (DLI) i próg różnicy częstotliwości (DLF). Pomiary te wykonano z użyciem obu programów, Psycon i MLP, z wyjątkiem czasu trwania bodźców w GDT.

Wyniki: Do określenia statystycznej istotności różnic pomiędzy MLP i Psycon użyto testu Wilcoxona dla par obserwacji (Wilcoxon signed-rank test). Wyniki pokazały brak istotnych różnic pomiędzy MLP a Psycon w odniesieniu do DLI, DLF i DDT. Znaleziono jednak statystycznie istotną różnicę w teście GDT.

Wnioski: Podsumowując, wyniki DLI, DLF i DDT można uogólnić dla Psycon i MLP. Jednak dalsze badanie z większą próbą mogłoby wzmocnić ustalenia obecnego badania.

Słowa kluczowe: metoda największej wiarygodności • psychoakustyka • MATLAB • Psycon • próg różnicy

Introduction

Psychoacoustics is the "branch of psychophysics involving the scientific study of sound perception" [1]. Psychoacoustics includes perceiving a sound's frequency, intensity, or temporal aspects [2,3]. Psychoacoustic abilities play a crucial role in speech perception. Evaluation of psychoacoustic skills can be done with various software and methods. Two frequently used applications to assess psychoacoustic abilities include Psycon and the maximum likelihood procedure (MLP) implemented in Matlab [4–8].

Grassi and colleagues described a maximum likelihood approach that adaptively changes the signal based on the responses received from previous trials. MLP hypothesizes multiple psychometric functions, which are referred to as hypotheses. According to the subject's responses, the maximum likelihood algorithm determines which hypothesis is most likely to be comparable to the subject's real psychometric function. MLP can track any point on the psychometric function and can be done using nAFC or yes/no tests [9].

Psycon is Windows software to conduct psychoacoustic studies with varied presentation intervals. Psycon uses the Auditory Syntax (AUX) scripting language, a programming syntax that helps describe and process auditory data [10]. Individuals who find programming in Matlab intimidating or who have less programming skills will benefit the most from AUX. Psycon supports methods where the stimulus is delivered randomly in numerous intervals, either "standard/reference" or "odd-ball/variable." The subject's goal is to choose the odd-ball stimulus's interval. Graphs visualize the procedure's progress during the testing session [10].

Psycon and MLP implemented in Matlab have been widely used to assess psychoacoustical abilities [4–8]. Studies have used these applications independently, and there is no literature comparing results across these two pieces of software. If the two applications give similar results, this will make it easy for researchers to generalize psychoacoustics data. The present study compares the results of various psychoacoustical abilities using Psycon and MLP.

Material and methods

Participants

For the study, a total of 39 participants (19 females and 20 males) between the ages of 18 and 26 years were chosen. Participants were selected based on a purposive convenient sampling strategy. Puretone audiometry was performed on all participants. All subjects' hearing sensitivity was within ≤ 15 dB HL at all speech frequencies, for both air conduction and bone conduction. To exclude middle ear infections, all participants underwent immittance audiometry. Tympanometry was performed using a 226 Hz probe tone, and acoustic reflex thresholds were measured at 0.5, 1, and 2 kHz. All participants had bilateral A-type tympanograms, and present acoustic reflexes, indicating a normal conductive mechanism.

Procedure

A battery of psychophysical tests to assess auditory discrimination and temporal resolution were administered: i.e., difference limen of frequency (DLF), difference limen of intensity (DLI), duration discrimination threshold (DDT), and gap detection thresholds (GDT). DLI assesses the subject's minimum intensity difference to discriminate between otherwise identical sounds. DLF evaluates the subject's minimum frequency difference to discriminate two closely spaced frequencies. DDT assesses the minimum difference in duration required to differentiate two sounds. GDT is used to measure the minimum gap, which a participant has to identify in the middle of broadband noise. These measures were assessed using the Psycon application and MLP implemented in Matlab. An attempt was made to keep the stimuli specifications similar in Psycon and MLP, except for the duration of the GDT stimuli. In Psycon the duration of the GDT stimuli was 300 ms [8] whereas in MLP it was 500 ms [4,7]. This was done in order to have better comparisons with earlier studies using the same platform [4,7,8]. All the test stimuli were routed binaurally at 60 dB HL using an audiometer. Randomization of the test was also ensured. The psychophysical tests session lasted approximately 45 minutes for each participant (with quiet intervals between sessions).

In Psycon (version 2.18), the psychoacoustic test stimuli were created using the AUX scripting language, consisting of definitions of signals and arithmetic operations. Signals used in the present study were based on tonal components for DLI, DLF, and DDT and noise components for GDT. A three-interval alternative forced choice (3IAFC) paradigm was used for all differential sensitivity measures with a 2-down and 1-up procedure to achieve a 70.7% response on the psychometric function [11]. Each test trial contained three blocks, two of which contained the standard stimulus and the third block containing the variable stimulus, which is randomly varied between trials by Psycon. Two programs (Psycon.exe and Psycon_response.exe) are included in the software. In Psycon.exe, the stimulus is presented as per the AUX code, and Psycon_response.exe allows the subject to respond. All the stimuli generated were cosine ramped for an initial and final 10 ms using corresponding AUX codes. The progress of the adaptive test procedure could be visualized on a monitor with graphs [10]. The procedure used to administer the DLF, DLI, DDT, and GDT tests is described in detail below.

Difference limen of frequency: DLF was estimated for a pure-tone signal of duration 250 ms and 1000 Hz in frequency. The interstimulus interval was set at 500 ms with an intertrial interval of 500 ms, and a sampling rate of 44.1 kHz. Out of three blocks on each trial, two contained the standard frequency, and one block had the variable frequency. The initial value of the variable frequency was 100 Hz, and the value varied based on the response from the subject. The variable frequency was presented randomly at each interval. An adaptive two-down, one-up procedure was utilized, with the initial step size being 25 Hz for the first five response reversals and a step size of 10 Hz for the final six response reversals. The subject was instructed to identify the high-pitched signal. The average of the last four reversals was considered to be the DLF threshold.

Difference limen of intensity: The DLI was estimated at a frequency of 1000 Hz and 250 ms in duration. The sampling rate was 44.1 kHz, and the interstimulus interval was set at 500 ms with an intertrial interval of 500 ms. Out of three blocks, two blocks were used as anchors, and one block was the variable that was louder than the other two blocks. The initial value of the variable intensity was 10 dB, which varied based on the response from the subject. An adaptive two-down, one-up procedure was utilized. The initial step size was 2 dB for the first five response reversals, with a step size of 1 dB for the final six response reversals. Subjects were instructed to identify the block which was louder. The average of the last four reversals was considered to be the threshold.

Duration discrimination threshold: The DDT was estimated at a frequency of 1000 Hz using a 250 ms stimulus.

The sampling rate used was 44.1 kHz, the interstimulus interval was set at 500 ms, and the intertrial interval was 500 ms. Out of three blocks on each trial, two blocks were the standard block, and one block contained the variable duration stimuli. The initial value of the variable duration was set at 100 ms, and was varied based on the response of the subject. At each interval, a stimulus of different duration was presented randomly. The individual was asked to identify the longer stimuli from the three blocks given. The threshold was calculated as the average of the previous four reversals.

Gap detection threshold: The stimulus was a 300 ms broad band noise (BBN) with a 1 ms cosine ramp at the offset of the leading marker and the onset of the trailing marker to avoid audible perceived silence in the center of the variable signal. The sampling rate was 22.05 kHz, with a 400 ms interstimulus interval and a 400 ms intertrial interval. Three blocks of BBN stimuli were employed, one of which included variable duration silence. The subject was told to find the block that contained the silence. The length of the silent interval was adjusted depending on the subject's responses. The minimum gap identified by the subject was taken to be the threshold.

The same psychoacoustic procedures were performed through the MLP toolbox implemented in Matlab (version 7.8.0, R2009a). The tests used a three-interval alternate forced choice adaptive technique to estimate a 79.4% response criterion. Each test trial consisted of three blocks, which included the standard stimulus and the third block containing the variable stimulus, chosen randomly by MLP. The participant was told to identify the block that contained the different stimulus. The detailed procedures for each test are described below.

Difference limen of frequency: DLF was estimated for a 1000 Hz pure tone with a 250 ms anchor duration and 10 ms raised cosine ramps at onset and offset. The variable stimulus's minimum and maximum frequency deviations were 0.1 and 100 Hz, respectively. The participant's task was to identify the variable block out of three. The frequency difference corresponding to the 79.4% point of the psychometric function was identified using MLP.

Difference limen of intensity: DLI was estimated for a 1000 Hz pure tone with an anchor duration of 250 ms and 10 ms raised cosine ramps at onset and offset. The minimum and maximum intensity deviations employed were 0.99 and 10 dB, respectively. The participant's task was to identify the variable block. The intensity difference corresponding to the 79.4% point of the psychometric function was calculated using MLP.

Duration discrimination threshold: DDT was estimated for a 1000 Hz pure tone with an anchor duration of 250 ms and 10 ms raised cosine ramps at onset and offset. The duration deviation was set to 0.1 and 200.1 ms, respectively. The participant's task was to identify the variable block. The duration difference corresponding to the 79.4% point of the psychometric function was calculated using MLP.

Gap detection threshold: GDT was measured using BBN. The smallest gap a participant could detect in the middle of a 500 ms BBN was measured. The minimum and maximum duration of the gap used was 0.1 and 64 ms. The participant's task was to identify the variable block. The gap difference corresponding to the 79.4% point of the psychometric function was calculated using MLP.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (version 20). The mean and standard deviation (SD) for all parameters for the two programs were calculated using descriptive statistics. The Shapiro-Wilk test was used to determine normality of the data, and the findings revealed a non-normal distribution for all parameters. The Wilcoxon signed-rank test was further used to assess the statistical difference for the psychoacoustical tests between the two pieces of software.

Results

This study compared DLI, DLF, DDT, and GDT obtained via Psycon and MLP. **Figure 1** shows the means and SD of these psychoacoustic measures tested in the two software programs. **Figure 1** shows that mean values are similar across Psycon and MLP. **Figure 2** is a scatter plot representing individual data across the software for all psychoacoustical tests. **Figure 2** shows that there are a few outliers in DLI and DLF measurements, and similar results are depicted between MLP and Psycon for all psychoacoustic measures. Additionally, the Wilcoxon signed-rank test revealed that there was no statistically significant difference in scores for DLI ($Z = -1.268$, $p = 0.205$), DLF ($Z = -1.335$, $p = 0.182$), and DDT ($Z = -1.487$, $p = 0.137$), but there was a statistically significant difference in gap detection threshold ($Z = -2.719$, $p = 0.007$) between the scores obtained across Psycon and MLP.

Discussion

Participants underwent routine audiological evaluation, and all had a bilateral normal hearing sensitivity. This study measured several psychoacoustic measures: DLI, DLF, DDT, and GDT using both the Psycon and MLP applications. Except for the length of the stimulus in GDT, similar stimulus parameters were attempted to be maintained between the Psycon and MLP software.This study is a preliminary attempt to compare psychoacoustic measures between these two applications. Psycon and MLP are widely used in research to assess psychoacoustic abilities.

The MLP toolbox is built into Matlab, and is a stand-alone platform which can be installed in various operating systems. Matlab is a heavy-duty software used to develop sophisticated algorithms [12], whereas in Psycon the user creates their desired stimulus using the AUX scripting language [10]. The current study took around 3 minutes to finish each test through MLP and 5 minutes to assess one psychoacoustic test in Psycon.

The preliminary results suggest no significant difference in DLI, DLF, and DDT between MLP and Psycon, although there was a significant difference in GDT. Therefore, psychoacoustic test findings for DLI, DLF, and DDT can be generalized between Psycon and MLP, but caution should

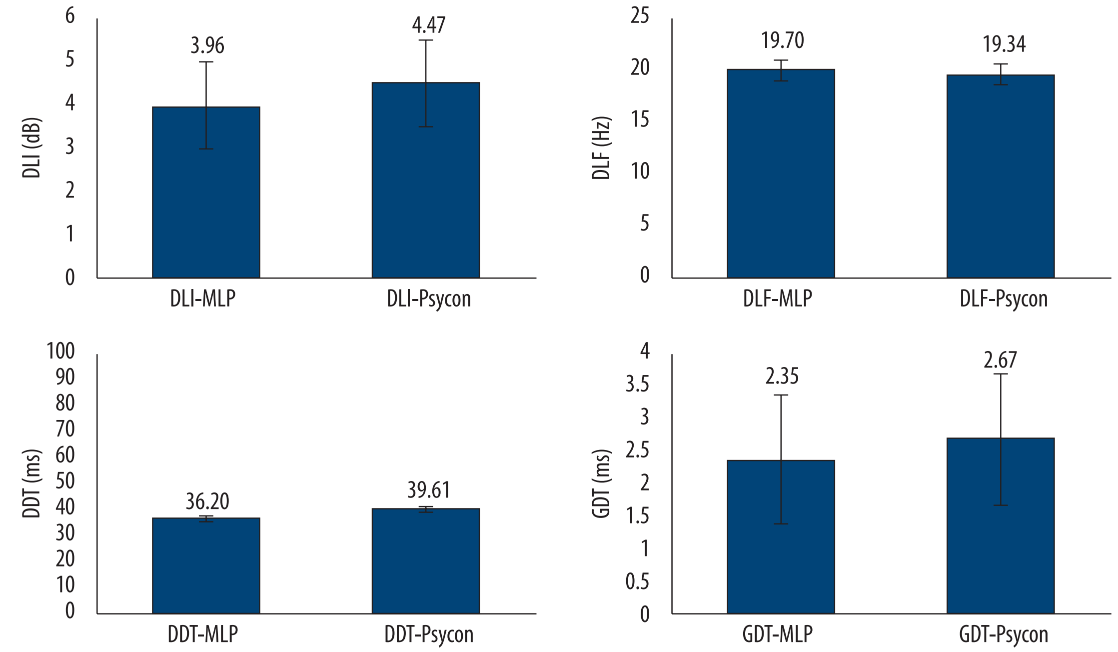

Figure 1. Means and SD of various psychoacoustic tests measured by MLP and Psycon

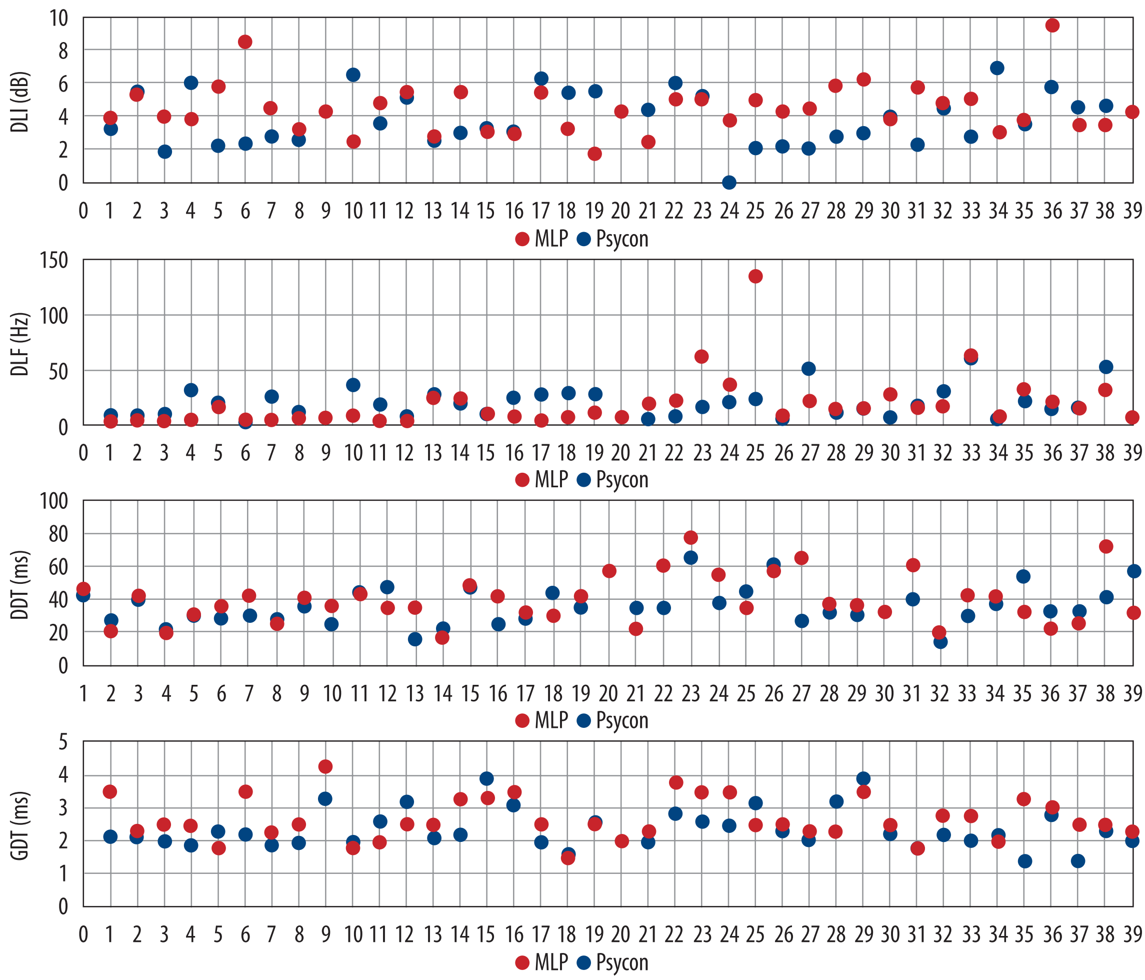

Figure 2. Scatter plots representing the individual scores for various psychoacoustic measures in MLP and Psycon

be taken when generalizing GDT test results. Looking closer at GDT, in MLP the stimulus duration used for BBN was 500 ms, but only 300 ms in Psycon; this difference might have influenced the outcome, since previous studies have shown that the gap detection threshold varies according to the duration of the stimulus [13]. Hence, the difference in GDT results across the two pieces of software can be attributed to the difference in duration. Thus, the results from the present study indicate that different platforms can be used to derive basic psychoacoustic measures, but researchers should exercise caution in the design and selection of stimulus parameters. More research with a larger sample size is required to support the current study's findings.

Conclusions

To summarize, the preliminary findings of this study suggest that there was no significant difference between the results obtained through MLP and Psycon for DLI, DLF, and DDT tests. Thus it can be concluded that the results of DLI, DLF, and DDT can be generalized between Psycon and MLP. However, we found a significant difference for GDT. A larger sample size with different age groups and different types of hearing loss would strengthen the current study's findings.

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