Research Article

Test-retest Reliability of Various Psychoacoustic Tests in Psycon Application

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Citation: Mathew S, Banumathi, Kumar S, Tanniru K, Jain C. Test-retest Reliability of Various Psychoacoustic Tests in Psycon Application. Aud Vestib Res. 2023;32(2):114-20.

https://doi.org/10.18502/avr.v32i2.12171

Highlights

- To assess the test-retest reliability of psychoacoustic measures using Psycon
- Good to excellent test-retest reliability was seen for various psychoacoustic tests

Article info:
Received: 13 Sep 2022
Revised: 28 Sep 2022
Accepted: 05 Nov 2022

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ABSTRACT

Background and Aim: Psychoacoustics includes studying the perceived effects of changes in sound intensity, temporal, and frequency aspects that are critical for speech perception. Psycon is one such software used in studies to assess psychoacoustic abilities. Psycon has the potential for wide clinical applications in psychoacoustic research and relies on Auditory syntaX (AUX), a program designed specifically to handle auditory signals. The current study aimed to determine the test-retest reliability of the Psycon application for differential sensitivity measures of frequency, intensity, duration and silence.

Methods: The study included 39 participants with normal hearing sensitivity. Psychoacoustic measures, namely, gap detection threshold, duration discrimination threshold, difference limen of intensity, and difference limen of frequency, were used to assess test-retest reliability. The test-retest reliability of all measures was checked in two separate sessions within one day.

Results: The reliability of each measure was measured using Cronbach's alpha. Test-retest reliability of various psychoacoustic tests measured with Psycon ranges from good to excellent. difference limen of frequency had the highest reliability, followed by duration discrimination thresholds, difference limen of intensity, and gap detection thresholds.

Conclusion: Psycon appears to be a reliable tool for assessing different psychoacoustic abilities.

Keywords: Psycon; psychoacoustics; reliability; difference limen; perception

Introduction

Psychophysics has been described as "the scientific study of the relation between stimulus and sensation" [1]. Psychoacoustics is a "branch of psychophysics involving the scientific study of sound perception" [2]. Psychoacoustics refers to the study of perceived effects of changes in sound intensity, temporal, and frequency aspects, which are critical for speech perception [3, 4]. Evaluating these abilities has piqued the interest of audiologists, psychologists, and acoustics experts. Several studies assessing psychoacoustical skills in people with normal hearing have been conducted. The results have been compared with the geriatrics, with an auditory processing disorder, hearing impairment, and auditory neuropathy [5, 6].

Recent research to assess auditory difficulties in hidden hearing loss has shown that standard audiological assessment, such as pure tone audiometry, is insufficient to detect hidden hearing loss [7]. Differential sensitivity measures could be useful indicators to detect such hidden hearing difficulties, which involves estimating the minimum amount of change in a systematic change in basic sound parameters such as frequency, intensity, duration, and silence. Many computer applications are available to measure differential sensitivity measures.

Psycon application is a free downloadable tool for psychoacoustic testing and research, developed by Kwon et al. [8], and is offered free under academic license 3.0. Audiologists and research students find Psycon an efficient platform for generating customized acoustic stimuli and instantly presenting stimuli in classical psychoacoustic paradigms [8]. Psycon relies on Auditory syntaX (AUX), a program designed to handle auditory signals. AUX is a programming syntax for describing and processing auditory information. The AUX implementation uses a device-independent programming paradigm that expresses sounds in a conceptual representation. AUX provides an alternate approach for generating signals by enabling a device-independent means of conceptually representing sounds. It's helpful for beginners without much programming knowledge and experienced programmers [8].

However, no research on the test-retest reliability of Psycon software has been reported. Therefore, there is a need to assess the test-retest reliability of Psycon for various psychoacoustic measures. The psychoacoustic measures evaluated in this study are differential sensitivity of frequency (for pitch discrimination), intensity (for loudness discrimination), duration (for time discrimination), and silence (for gap discrimination).

Methods

For the current study, a total of thirty-nine participants (20 males and 19 females) were chosen in the age range of 18 to 25 years. A purposively convenient sampling strategy was used to select participants. All participants underwent basic audiological testing, including otoscopy, immittance evaluation, pure tone, and speech audiometry in an acoustically treated room. All the participants in the study had hearing sensitivity within normal limits in both ears, that is, a threshold less than 15 dB hearing level from frequency ranging from 0.25 kHz to 8 kHz and 0.25 kHz to 4 kHz for air conduction and bone conduction, respectively [9]. Participants with only 'A' type of tympanogram on acoustic immittance measures and the presence of acoustic reflexes at 0.5 kHz, 1 kHz, and 2 kHz [10] were included in the study.

Gap Detection Thresholds (GDT) [11], Duration Discrimination Thresholds (DDT) [12], Difference Limen of Frequency (DLF) [13], and Difference Limen of Intensity (DLI) [14] were chosen to represent differential measures in basic sound parameters and are measured using the Psycon program. With the help of the AUX scripting language, the psychoacoustic test stimuli were generated in the Psycon application [8]. Three blocks made up each test trial: two blocks included the regular stimulus, while the third block contained the variable stimulus, which was chosen randomly by Psycon. The individual was instructed to indicate the block that held the variable stimuli. The audiometer was used to route all the test stimuli presented binaurally at 60 dB HL. GDT, DDT, DLI, and DLF testing were repeated within 24 hours to measure the test-retest reliability [15]. The retesting was done within 24 hours to reduce the influence of external factors such as the health status of the individuals and environmental factors. Each psychoacoustic test's specific procedure is given below.

Difference limen of intensity

DLI was calculated using a 250 ms stimulus at 1000 Hz frequency. In each trial, three blocks were employed: two with standard stimuli and one with varied duration stimuli. The sampling rate was 44100 Hz, the interval between stimuli was 500 ms, and the time between trials was 500 ms. Initially, the variable intensity was set at 10 dB, and the value was adjusted based on the subject's response. An adaptive two down, one up technique was adopted, with the initial step size of 2 dB for the first five response reversals and a step size of 1 dB for the final six. The participants were asked to identify the variable block. The threshold was determined by averaging the last four reversals [16].

*Standard/reference interval: dB (–20) *ramp [tone (1000, 250), 10]*

*Oddball/ adjustable interval: dB (–20+v) *ramp [tone (1000, 250), 10]*

Difference limen of frequency

DLF was determined for a 1000 Hz pure tone with a duration of 250 ms. Three blocks were employed in each trial, two with the standard frequency and one with the variable frequency. The sampling rate was 44100 Hz, while the interstimulus and intertrial intervals were 500 ms. The variable frequency was initially set at 100 Hz, and the value fluctuated based on the participants' responses. The variable frequency was provided at random during each testing interval. This procedure was carried out in a two-down, one-up manner, with an initial step size of 25 Hz for the first five response reversals and a step size of 10 Hz for the final six response reversals. It was instructed that the participant should identify the high-pitched signal. The DLF threshold was based on the average of the last four reversals [16].

*Standard/reference interval: dB (–20) *ramp [tone(1000, 250), 10]*

*Oddball/ adjustable interval: dB (–20) *ramp [tone(1000+v, 250), 10]*

Duration discrimination threshold

A stimulus of 250 ms duration at a frequency of 1000 Hz was utilized to quantify the DDT. Each trial had three blocks, two of which were standard and one of which contained varied length stimuli. The sampling rate was 44100 Hz, while the interstimulus and intertrial intervals were 500 ms. The variable duration's starting value was set to 100 ms, which was adjusted depending on the subject's response. At each interval, the variable duration stimuli were provided at random. The participant was instructed to indicate the lengthier stimuli among the three blocks. The threshold was established by averaging the last four reversals [16].

*Standard/reference interval: dB (–20) *ramp [tone (1000, 250), 10]*

*Oddball/ adjustable interval: dB (–20) *ramp [tone (1000, 250+v), 10]*

Gap detection threshold

The stimulus was Broad Band Noise (BBN) of 300 ms duration with a 10 ms cosine ramp at the offset of the leading marker and the onset of the trailing marker to avoid any audible perceived silence at the variable signal's center. The interstimulus and intertrial intervals were 400 ms long, and the sampling rate was at 22050 Hz. Three blocks of BBN were used to calculate GDT, one of which had variable-length silence. The participant had to indicate which block had the silence. Depending on the subject's response, the duration of the silence was changed. The criteria were based on the subject's smallest gap [16].

*Standard/reference interval: dB (–10) *ramp [noise (300), 10]*

*Oddball/adjustable interval: dB (–10) *ramp [(noise (150-v)++silence(v)++noise(150-v)), 10]*

Analyses

The current study's data were statistically analyzed with IBM SPSS (version 20). All parameters' mean and standard deviation (SD) were computed using descriptive statistics over the two sessions. The Shapiro-Wilk test was performed to determine the data's normality, and all the parameters revealed non-normal distributions. Cronbach's alpha, a well-known reliability metric for data outside normal distribution, was used to analyze test-retest reliability.

Results

This study used the Psycon application to determine the test-retest reliability of several psychoacoustic measures. The mean and SD of DLI was 4.4 dB (SD=1.68) and 3.9 dB (SD=1.60) in the first and second sessions, respectively. DLF's mean and SD were 19.5 Hz (SD=10) and 18.75 Hz (7.5) across two test sessions. The DDT results were 39.9 ms (SD=14.5) and 35.8 ms (SD=12.3) in the first and second test sessions. For GDT, the mean were 2.4 ms (SD=0.57) and 2.6 ms (SD=0.59) in the first and second sessions, respectively. Figure 1 illustrates the mean and standard deviation of DLI, DLF, DDT, and GDT across two testing sessions. In Figure 1, we can see that the mean scores obtained across two sessions are almost identical. Figure 2 depicts a scatter plot display-

Table 1. Cronbach's alpha values for each of the psychoacoustical measures across sessions

Psychoacoustic measure	Cronbach's alpha	Reliability	ICC	ICC lower CI	ICC upper CI
Difference limen of intensity	0.873	Good correlation	0.873	0.757	0.933
Difference limen of frequency	0.994	Excellent correlation	0.994	0.989	0.997
Duration discrimination threshold	0.907	Excellent correlation	0.907	0.832	0.951
Gap detection threshold	0.813	Good correlation	0.814	0.643	0.902

ICC; intraclass corelation, CI; confidence interval

ing individual data for all psychoacoustical assessments over two sessions.

According to the results, the test-retest reliability of different psychoacoustic measures evaluated using the Psycon program ranged from excellent to good. A good correlation was noted for GDT and DLI, and an excellent correlation for DDT and DLF. The Cronbach's alpha for DLI was 0.873; for DLF, it was 0.994; and for DDT and GDT, it was 0.907 and 0.813, respectively. Cronbach's alpha values, reliability, Intraclass Correlation (ICC), and upper and lower ICC confidence interval for each of these psychoacoustic parameters assessed in Psycon are shown in Table 1.

Discussion

This study measured the test-retest reliability of several psychoacoustic measures, namely GDT, DDT, DLI, and DLF, using the Psycon application [12-14, 17] The results obtained in the study are consistent with differential threshold of duration of 35 msec [15] and of gap detection 2.3 msec [15], 3 msec [18] and 3.1 msec [19] obtained from other studies. Slightly better results were obtained in the present study for the differential thresholds of frequency 23.5 Hz [15] and differential thresholds of the intensity of 7.2 dB [15]. These differences can be attributed to the spectral differences in the auditory signals generated by different applications. Further, present results indicate differential sensitivity measures in temporal aspects are more consistent than other parameters like frequency and intensity.

The psychoacoustic measures utilizing Psycon showed excellent to good test-retest reliability, with DLF having the highest reliability, followed by DDT, DLI, and GDT. There has been no explicit study in the past on test-retest reliability of psychoacoustic measures in Psycon. This study is a preliminary attempt to establish the reliability of psychoacoustic measures assessed using Psycon.

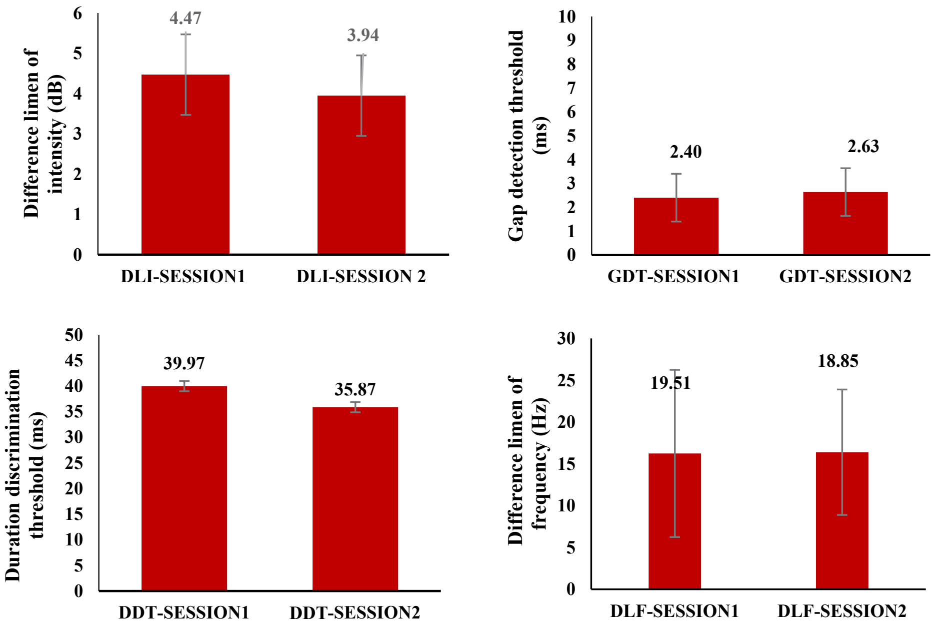

Figure 1. The means and standard deviations of various psychoacoustic tests conducted in sessions 1 and 2. DLI; difference limen of intensity, GDT; gap detection threshold, DDT; duration discrimination threshold, DLF; difference limen of frequency

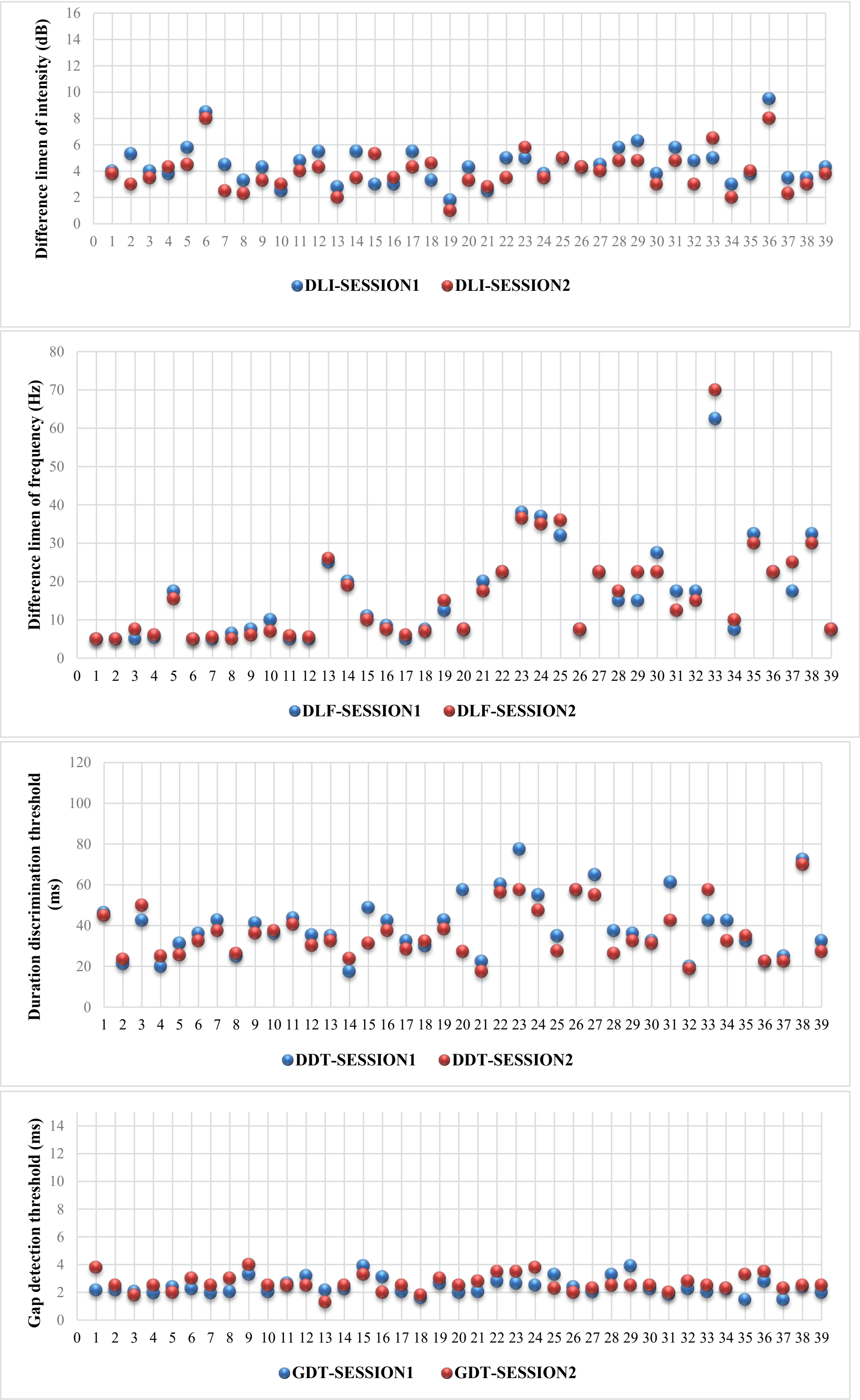

Figure 2. Individual psychoacoustic scores for sessions 1 and 2 were plotted on a scatter plot. DLI; difference limen of intensity, DLF; difference limen of frequency, DDT; duration discrimination threshold, GDT; gap detection threshold

Psycon is an application that is helpful for beginners with little or no programming experience and even experienced programmers. Each psychoacoustic measure assessment took approximately 4 minutes. Thus, it takes a reasonable amount of time for each run of testing, and it's not a time-consuming program. Any psychoacoustic tool must demonstrate high test-retest reliability to be able to use for clinical and research purposes. It helps us determine whether the variance caused is a real difference between target and control groups, regardless of the time or user profile [20]. The current findings imply that the Psycon tool can be reliably used in studies of psychoacoustics for clinical and research purposes.

Conclusion

Using Psycon, the retest reliability of some psychoacoustic measures ranges from excellent too good. However, the current results would be supplemented by a more extensive study with more individuals and across sessions. In the future, the performance through Psycon can be compared with other computer applications.

Ethical Considerations

Compliance with ethical guidelines

The current manuscript protocol complies with the recommendations of the Declarations of Helsinki and Tokyo for humans and are approved by institutional Ethics Committee. Authors are responsible for all statements made in their work.

Funding

This research did not receive any specific grant from the public, commercial, or not-for-profit funding agencies.

Authors' contributions

SM, B, SK: Acquisition of data and drafting the manuscript; KT: Study design and supervision, interpretation of the results, and critical revision of the manuscript; CJ: Study design, supervision, interpretation of the results, critical revision of the manuscript, and statistical analysis.

Conflict of interest

The author reports no conflicts of interest in this work.

Acknowledgements

The authors appreciate the support from the Research Center at the College of Applied Medical Sciences and the Deanship of Scientific Research at King Saud University, Kingdom of Saudi Arabia, and Director, All India Institute of Speech and Hearing, Mysuru.

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