

Research Article

Musical Skills and Auditory Processing in Music Trainees

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Short running title: Musical Skills and Auditory Processing in...

Highlights

Link between psychoacoustical abilities and perception of musical skills was studied

Teachers assessed musical ability based on specific psychoacoustic parameters

Teachers' rating correlated with temporal resolution and 1000 Hz difference limen

ABSTRACT

Background and Aim: Controversy exists regarding the link between the psychoacoustical measures and the perceptual rating of musical skills. The study aimed to determine whether the perception of musical abilities, as rated by music teachers, is associated with specific psychoacoustical abilities.

Methods: Twenty-seven children who had undergone Carnatic music training for a duration of 2 months to 1 year were assessed using three psychoacoustical tests: Gap Detection Test (GDT), Duration Discrimination Test (DDT), and Difference Limen of Frequency (DLF) tests. Two music teachers, with different teaching experiences, rated their pitch, rhythm, tempo, auditory memory, and overall musical abilities.

Results: The inter-rater reliability was found to be excellent, suggesting that the ratings given by both teachers were similar. A Spearman's rank correlation test showed a moderate significant correlation between rating scores awarded by the teachers and the thresholds obtained by the trainees on the psychoacoustical tasks. These correlations were seen between temporal resolution (GDT) with the rating of the teachers for auditory memory ($r=-55$, $p=003$), and between frequency discrimination at mid-frequency stimuli (DLF at 1000 Hz) and the rating by the teachers for tempo ($r=-62$, $p=000$). A principal component analysis also grouped GDT and DLF at 1000 Hz with the ratings of the teachers, substantiating the findings of the correlation.

Conclusion: The findings indicated that music teachers are able to provide information only on a few acoustical aspects when rating music trainees. Hence, to get more specific information about the musical abilities of trainees, they should be evaluated using psychoacoustical measures.

Keywords: Musical training; gap detection threshold; duration discrimination test; difference limen for frequency; rating scale

Introduction

Musical training has been found to have a positive influence on the auditory skills of music trainees. Such training was reported to improve their psychoacoustic skills [1-4]. These psychoacoustical skills include temporal processing skills [2], discrimination of frequency [3], and intensity discrimination [1]. Unlike Jain et al. [1], the other studies have reported no improvement in the intensity discrimination skills [5, 6]. However, improvement in frequency discrimination and temporal processing is reported in the literature.

The specific temporal processing skills that were reported to change following musical training included gap detection [1], and duration discrimination [4]. Similarly, enhancement in frequency discrimination has also been reported in music trainees [1]. Thus, it is evident that individuals with musical training have better temporal processing skills and frequency discrimination compared to those without such training. In contrast, it has been observed that music training did not enhance psychoacoustical abilities [5-7].

Besides determining the benefit of musical training using psychoacoustical measurements, researchers have also utilised perceptual rating scales [8]. Saunders and Holahan [9], found that the criteria-specific music rating scales closely described the perceived level of performance of trainees. This technique was considered as a way to select the best perceivable music skill of the trainees without personal preferences or agreeing on any indeterminate standard. Further, they noted that rating scales had the added advantage of ease of use, enabling them to be utilised frequently to record the progress of trainees and to provide them feedback. Similarly, Gordon [8] reported that a performance rating scale for musicians enabled the teacher to give sequential directions to the trainees and make them achieve the required objective or target musical skill.

The experience of the teacher has also been observed to have an impact on the ratings of the musical abilities of students [10]. Madsen and Cassidy [11] found that more experienced teachers rated the students lower than the less experienced teachers. Experienced musical teachers were found to be more critical in their evaluation compared to preservice music teachers [12]. Thus, studies indicate that the experience of teachers have an impact on evaluation.

Limited literature exists regarding the link between the psychoacoustical measures and the perceptual rating of musical skills. Parthasarathy and Yathiraj [13] found no significant correlation between three psychoacoustical tests (frequency discrimination test, duration discrimination test, and gap detection test) of music trainees and their teachers' assessment of their musical skills on a 5-point rating scale. This lack of correlation was attributed to the 5-point rating scale, which limited the teachers from differentiating the musical abilities of the children. It has been reported in the literature that scales with larger category-points enable the user to provide more information [14], resulting in increased reliability [15], and were preferred compared to scales with fewer category-points [16]. A 10-point rating scale has been preferred to fewer [16] or more category points [17]. Thus, the study aimed to determine whether the perception of musical abilities, rated by music teachers on a 10-point rating scale, is associated with specific auditory processing abilities in music trainees, measured using psychoacoustical tests. The study also aimed to assess the influence of the teacher's years of experience on the rating of trainees' musical abilities.

Methods

The study was conducted in two phases using a causal research design. Phase-I involved assessing children who were undergoing Carnatic music training using three psychoacoustic tests [Gap Detection Threshold (GDT), Duration Discrimination Test (DDT), and Difference Limen for Frequency (DLF)], which could give insight about their temporal and frequency perception. In phase-II, two teachers who taught Carnatic music rated specific musical abilities of children using a Music Rating Scale, a modified version of the scale developed by Parthasarathy et al. [13]. The study was carried out following the ethical guidelines of the institute.

Participants

Using a purposive sampling technique, children who had undergone Carnatic music training from 2 months to 1 year were studied. Thirty children (9 males and 21 females), aged 6 to 10 years (mean=8.48 years, SD=1.16) were studied. Informed consent was obtained from the parents. The participants had no prior formal musical training before enrolling in the music class. Furthermore, they did not come from families engaged in any form of musical training, and their home practice after the training sessions was minimal. The participants had no history of any speech-language or hearing problems when screened using the WHO Ten Questions for Disability Screening [18]. They attended music classes twice a week, with each session lasting 45 minutes. The trainees were taught alternatively by two different teachers, with each teacher training the children once a week. The children received training in batches of not more than ten children per session. Both teachers were qualified to

teach Carnatic music (Vidwath in Carnatic music). One teacher possessed ~25 years of experience, while the other had ~5 years of experience. All the trainees were trained on a pre-designed hierarchy of lessons.

Procedure

All children were evaluated using three psychoacoustical tests (GDT, DDT, DLF) to assess their temporal resolution, duration discrimination, and frequency discrimination perception. The order in which the three tests were assessed for each participant was randomised to avoid a test-order effect. Between tests, breaks were provided to prevent boredom or fatigue. The three tests were evaluated in a quiet room having no visual or auditory distractors. The ambient noise level within the room, measured using a sound level meter (Bruel & Kjaer 2238), ranged from 40 to 44 dBA.

The stimuli for all three tests were generated using the 'Maximum Likelihood Procedure' (MLP) m-code [10] with a sampling rate of 44100 Hz. The stimuli were generated and presented through a personal laptop loaded with the MATLAB (version 7.10) toolbox. The participants heard the output from the laptop through a Sennheiser HD 206 headphone. The thresholds were obtained for each of the psychoacoustical tests as per the method given by Grassi and Soranzo [19]. Using the software, the thresholds were estimated corresponding to a 79.4% detection probability point for a 3-down 1-up staircase method.

The stimuli were presented to either the right or left ear of the participants at 65 dB SPL using a three-alternative forced-choice method. Half of the participants were tested in their right ear and the other half in their left ear, to avoid an ear effect. Both ears of the participants were not evaluated to prevent a fatigue effect. The MLP code was written such that the presentation for each stimulus was estimated by the participants' previous response. The participants were instructed to indicate orally after each stimulus presentation as to which of the three stimuli heard by them was different by saying first, second or third. These responses were keyed into the laptop by one of the experimenters. No practice trials were given to all participants, but the test was started only when the child confirmed understanding of the instructions by indicating what they had to do. The procedure used to measure each test is described below.

Gap detection threshold

The GDT of the participants was evaluated using gap durations ranging from 0.1 ms to 64 ms inserted in the centre of 750 ms white-noise segments. The duration of the gap, inserted into one of the three noise segments presented at a time, was randomised by the software. The stimulus in which the gap occurred within the triad was also randomised. The test commenced using a gap of 64 ms. The participants were instructed to identify which of the three stimuli they heard had a gap. If the response was correct, the gap duration automatically decreased until a wrong response was obtained, after which the gap duration increased. The lowest gap duration that could be detected was noted as the threshold.

Duration discrimination test

DDT was assessed using a 1000 Hz standard tone having a 250 ms duration and variable tones that had durations ranging from 0.1 ms to 200.1 ms. Each presentation heard by the participants contained two standard tones and one variable tone. They were instructed to identify the longest stimulus heard. If the participants responded correctly, the duration of the subsequent variable tone was automatically reduced by the software. The DDT threshold was calculated as the smallest duration difference that could be discriminated.

Difference limen for frequency

The DLF was obtained for three standard pure-tones (500 Hz, 1000 Hz, and 4000 Hz). For each of these tones, the frequency of the deviant stimuli varied from the standard stimuli by a minimum of 0.1 Hz. The maximum frequency variation of the deviant stimuli was 10% of standard frequencies (50 Hz for 500 Hz, 100 Hz for 1000 Hz, and 400 Hz for 4000 Hz). The order in which the three standard tones were presented was randomised to minimise a test order effect. The test commenced with the maximum difference between the standard and deviant stimuli. For each standard tone, the participants had to identify which three stimuli (2 same and one deviant) had the higher frequency. If the response was correct, the frequency of the deviant stimulus was automatically reduced by the software. The smallest frequency difference that the participants could identify was noted. This was done for each of the standard frequencies.

Among the 30 children who were evaluated, three were unable to carry out the tasks as per the instructions given to them and hence were eliminated from the study. Hence, the data from the 27 children (7 males and 20 females), who met the required psychometric criteria, were documented and further subjected to statistical analyses.

Procedure for teacher rating of music abilities

A Music Ability Scale [13] designed to assess the musical skills of children undergoing musical training, had five domains. Four of the domains assessed specific auditory skills (pitch, tempo, rhythm, and auditory memory), and one assessed the overall musical skills. The scale was originally developed to obtain responses on a 5-point rating scale. However, as the five-point rating scale did not differentiate the finer musical skills of children with varying abilities, a ten-point rating scale was used. Additionally, the scores were labelled to enable the judgment across raters to be similar (<2=poor; 3 to 4=average; 5 to 6=above average; 7 to 8=good; 9 to 10=excellent). The two music teachers assessed the musical abilities of the children independently using the scale. Both teachers rated each of the participants twice, within a time interval of a week to determine the test-retest reliability. The scores obtained by each child on the five domains were summed to obtain a total score, separately by each teacher.

Statistical analysis

The data obtained were subjected to statistical analyses using SPSS (Version 21). As the data were found to be not normally distributed on a Shapiro-Wilks test ($p < 0.05$), non-parametric statistics were used. Descriptive and inferential statistics were carried out. For each of the psychoacoustic measures, the mean and median thresholds were calculated, along with the standard deviation and interquartile range. The scores given by each teacher were checked for intra-rater and inter-rater reliability by performing a Cronbach's alpha test. Initially, the effect of ear, age, and gender was analysed using a Mann-Whitney U test. A Spearman's rank correlation with a Bonferroni correction was measured to determine the relation between the ratings of the teachers and the psychoacoustic responses. Additionally, a non-parametric PCA was carried out to identify the components that load together using a Varimax rotation for the twelve variables studied. Utilizing the syntax script for non-parametric PCA developed by Marta Gracia-Granero (2006), the analysis was conducted.

Results

The responses of the participants on the three psychoacoustical tests (GDT, DDT, DLF) and the ratings given to the trainees on the Music Ability Scale were subjected to statistical analyses. The mean, standard deviation, median and interquartile range of the thresholds obtained for the different psychoacoustical tests carried out are provided in Table 1.

The intra-rater reliability was found to be good for teacher 1 ($\alpha = 0.85$), who had an experience of 20 years, and excellent for teacher 2 ($\alpha = 0.91$), who had an experience of 5 years. Likewise, the inter-rater reliability, was also found to be excellent for the first rating ($\alpha = 0.90$) and good for the second rating ($\alpha = 0.86$). As the ratings of both music teachers were similar, the average of their four ratings was used for further analyses. The mean, standard deviation, median, and interquartile range of the average of the ratings are given in Table 2.

A Mann-Whitney U test showed that there existed no significant difference in the thresholds obtained on those evaluated in the right ear with those evaluated in the left ear for all five psychoacoustic measures that were evaluated (GDT: $U = 65.5$, $p = 0.236$; DDT: $U = 81$, $p = 0.68$; DLF at 500 Hz: $U = 80.5$, $p = 0.65$; DLF at 1000 Hz: $U = 83.0$, $p = 0.76$; DLF at 4000 Hz: $U = 68.5$, $p = 0.30$).

No significant difference between males and females was observed for all parameters evaluated on a Mann-Whitney U test. This lack of difference was observed in each age group ($U = 69$, $p = 0.06$) and duration of training ($U = 67$, $p = 0.168$). Likewise, the thresholds were not significantly different between the males and females for GDT ($U = 68$, $p = 0.11$), DDT ($U = 69$, $p = 0.06$), DLF 500 Hz ($U = 47.5$, $p = 1.26$), DLF at 1000 Hz ($U = 45$, $p = 1.40$), DLF at 4000 Hz ($U = 47$, $p = 1.27$). Similarly, no effect of gender was observed for the average of teachers' ratings for pitch ($U = 56.5$, $p = 0.74$), rhythm ($U = 44$, $p = 1.45$), tempo ($U = 62.5$, $p = 0.42$), auditory memory ($U = 53.5$, $p = 0.92$), overall performance ($U = 54$, $p = 0.89$), and total rating score ($U = 50.5$, $p = 1.08$). Hence, the data of the males and females were combined for further analyses.

A Spearman's rank correlation test, after a Bonferroni correction, showed a moderate significant correlation between only two pairs of measures. GDT correlated significantly with the rating given for 'auditory memory' ($r = -0.55$, $p = 0.003$) and DLF for 1000 Hz correlated significantly only with tempo rating ($r = -0.62$, $p < 0.001$). In contrast, DDT, DLF for 500 Hz and DLF for 4000 Hz had no significant correlation with any of the domains of the Music Ability Scale (Figure 1).

The data were found to be suitable to conduct PCA, as the Bartlett's test of sphericity was significant ($\chi^2(66)=297.74$, $p<0.05$), and the Kaiser-Meyer-Olkin index was 0.65. Twelve components were identified, of which four components had eigenvalues of >1 (Figure 2). The four components accounted for 44.97%, 17.11%, 10.52% and 9.78% variability, respectively and had a cumulative variance of 82.37%. The factor loadings and communalities are provided in Table 3. It was found that component 1 contained the maximum number of variables, followed by component 2. Although the loadings were low for some of the variables, their communality and Kaiser-Meyer-Olkin index were high. The highest communality was observed for the total rating score obtained, while the duration of training had the lowest communality.

Discussion

The excellent to good intra-rater and inter-rater reliability of the teachers' ratings indicated that the music teachers assessed the musical skills of the children consistently across the domains that were evaluated. This occurred despite the number of years of experience of the two teachers being different. This is in contrast to previous studies that found differences between teachers with different durations of experience [10-12]. This lack of difference between the teachers is attributed to the junior teacher being trained by the senior teacher, which could have led to the former performing like the latter.

The age of the trainees of the current study did not correlate with the psychoacoustical test findings or the ratings given by the teachers. Also, a gender difference was not observed across the different psychoacoustical tests. This is similar to what has been reported regarding children who have not undergone any formal music training [20, 21].

Among the psychoacoustical measures evaluated on the trainees, temporal resolution (GDT) and frequency discrimination (DLF for 1000 Hz standard tone) had the highest significant correlation with the ratings given by the music teachers. The PCA also indicated that GDT was included in all four components identified. This highlights that the temporal resolution abilities of the trainees influenced the ratings of their music teachers. Temporal resolution not only correlated/loaded along with temporal skills, but it also did so with frequency/pitch-related parameters. Possibly, temporal resolution enabled the trainees to distinguish subtle acoustical variations, which made it possible for them to perceive multiple acoustic parameters, including pitch/frequency perception and auditory memory.

The influence of temporal resolution on other auditory processes has been established by Vaidyanath [22]. The study demonstrated that temporal resolution training brought about an improvement not only in temporal resolution but also in auditory memory, auditory closure, temporal pattern, and binaural integration. This suggests that temporal resolution plays a significant role in facilitating the perception of other auditory processes.

However, Parthasarathy and Yathiraj [13], who conducted a similar study as the current one on 14 music trainees, found no significant correlation between the results of psychoacoustical tests (GDT, DDT, and DLF for 500 Hz, 1000 Hz, and 4000 Hz) and the ratings given by a music teacher. The primary difference between the two studies was the use of a 5-point rating scale by the teachers in the earlier study, while a 10-point rating scale was used in the current study. It is possible that, with the 5-point rating scale, many trainees would have been grouped together, despite their differing abilities. With the use of a 10-point scale, subtle differences between the participants' skills could have been differentiated, thus distinguishing the musical abilities of the participants. The utility of a 10-point scale, compared to a 5-point scale, concurs with the recommendations given in the literature [16].

Further, the findings of the PCA in the current study showed that the frequency discrimination abilities of the trainees were found to be associated with the duration of training that they underwent. This was observed in principal components 1 and 2. This suggests that with the increase in duration of training, the frequency discrimination skills improved. A few of the psychoacoustical test responses (DDT, DLF at 500, and 4000 Hz) did not load with the ratings given by the teacher, suggesting that the teachers rated the musical skills of the trainees primarily based on DLF for a mid-frequency (1000 Hz) and GDT. This indicates that music teachers evaluate music skills primarily based on auditory temporal cues and mid-frequency cues, rather than low and high frequencies or absolute duration measures. This probably occurred as pitch discrimination at 500 Hz and 4000 Hz is less directly associated with cues used for music perception. Lower frequency cues have been reported to primarily convey prosodic and formant information, while higher frequencies are linked to timbral qualities rather than melodic accuracy [23]. Also, the teachers may have focused on the mid-frequency while rating the children, as it occurs relatively more often than the lower and the higher frequencies. The absence of a correlation

with duration discrimination can be attributed to teachers focusing on relative temporal variations (rhythm and tempo) when evaluating musical performance, which may not directly correspond to absolute duration discrimination abilities.

The importance of objective tests over subjective ratings while assessing the music performance of trainees has also been reported in the literature [8]. Thus, based on the findings of the current study and studies reported in the literature, it is recommended to use psychoacoustical tests for assessing auditory abilities, rather than subjective rating scales. However, it is recommended that a larger sample be evaluated to confirm the findings of the current study.

Conclusion

The study evaluated the relation between the perception of musical abilities rated by music teachers and specific psychoacoustic abilities of music trainees, and found a correlation between temporal resolution as well as frequency discrimination of mid-frequencies signals and the teachers' ratings. This suggests that music teachers rate the musical abilities of trainees based on specific psychoacoustic parameters. However, they do not rely on other psychoacoustical measures such as duration discrimination test and discrimination at lower (500 Hz) and higher (4000 Hz) frequencies. These findings indicate that music teachers only focus on a few psychoacoustical measures when rating music trainees. Hence, to get more information about the musical abilities of trainees, they should be evaluated using psychoacoustical measures.

Ethical Considerations

Compliance with ethical guidelines

The study was carried out following the ethical guidelines of Jagadguru Sri Shivarathreeshwara Academy of Higher Education and Research with reference number JSSMC/IEC/130624/17NCT/PY/2024-25. The study was carried out with the verbal consent from the parents of the children who participated in the study.

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Authors' contributions

PS: Study design, acquisition of data, analyses of data and interpretation of results, literature review and drafting the manuscript; AY: Study design, supervision, interpretation of the results, drafting the manuscript and critical revision of the manuscript.

Conflict of interest

The authors have no conflicts of interest to declare.

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Table 1. Mean thresholds, standard deviation, median thresholds, and interquartile range of gap detection test, duration discrimination test and difference limen for frequency for 500 Hz, 1000 Hz and 4000 Hz

	Mean thresholds	Standard deviation	Median thresholds	Interquartile range
GDT (ms)	3.82	2.62	3.12	2.28
DDT (ms)	100.90	40.32	92.28	42.35
DLF for 500 Hz (Hz)	38.64	11.16	37.16	22.81
DLF for 1000 Hz (Hz)	68.96	31.16	74.69	62.74
DLF for 4000 Hz (Hz)	232.77	110.31	234.53	179.81

GDT; gap detection test, DDT; duration discrimination test, DLF; difference limen for frequency

Table 2. Mean, standard deviation, median, and interquartile range of the average ratings of musical skills

	Mean	Standard Deviation	Median	Interquartile range
Pitch	3.30*	0.78	3.25*	1.00
Tempo	3.23*	0.86	3.25*	1.50
Rhythm	3.34*	0.90	3.25*	1.00
Auditory memory	3.5*	0.89	3.50*	1.25
Overall performance	3.91*	0.93	4.00*	1.25
Total score	17.39**	4.16	17.75**	5.25

* Maximum possible score=10, ** Maximum possible score=50

Table 3. Loadings and communalities of the principal components analysis for the parameters assessed on the music trainees (psychoacoustical tasks, rating scores by the music teachers, and duration of training undergone by the trainees)

Variables	Components				Communalities
	1	2	3	4	
Total rating score	0.93				0.98
Pitch rating	0.92				0.84
Auditory memory rating	0.90				0.91
Overall rating	0.83	-0.30			0.90
Rhythm rating	0.83				0.79
Tempo rating	0.73		-0.35	-0.34	0.91
DLF 4000		0.83			0.70
DLF 500		0.73		0.42	0.73
Duration of training	0.39	-0.66			0.60
DDT			0.94		0.92
DLF 1000	-0.41			0.74	0.80
GDT	-0.50	0.38	-0.33	-0.57	0.82

DLF; difference limen for frequency, DDT; duration discrimination test, GDT; gap detection test

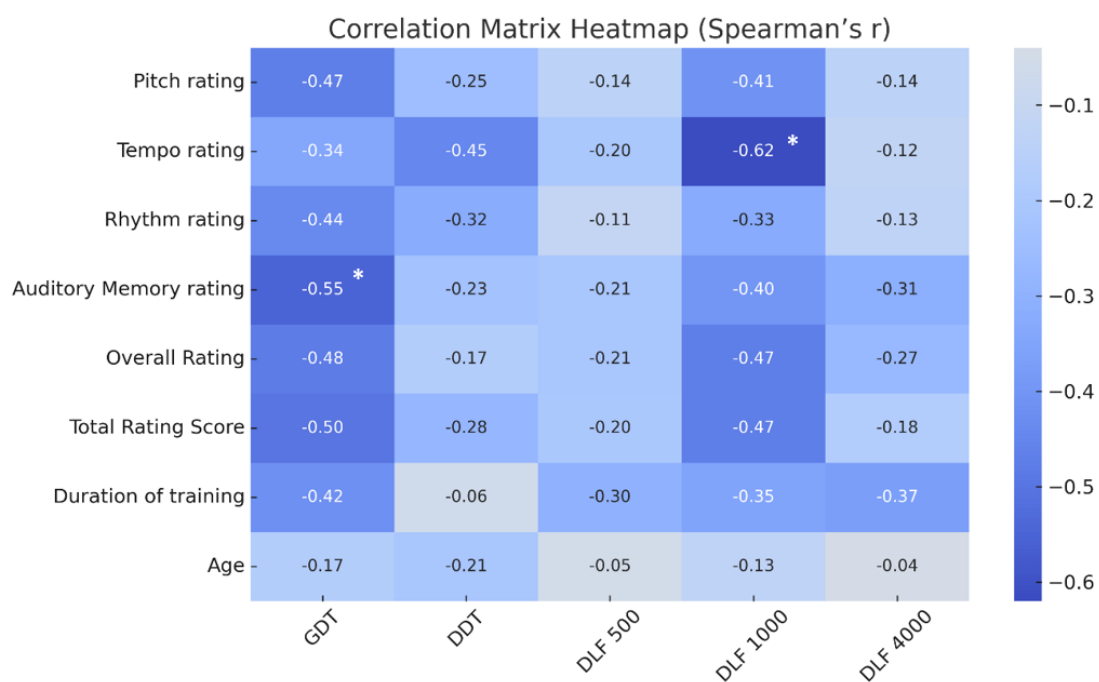


Figure 1. Correlation matrix heatmap representing the Spearman's correlation between average rating scores, psychoacoustical tasks, duration of training and age of trainees. GDT; gap detection test, DDT; duration discrimination test, DLF; difference limen for frequency

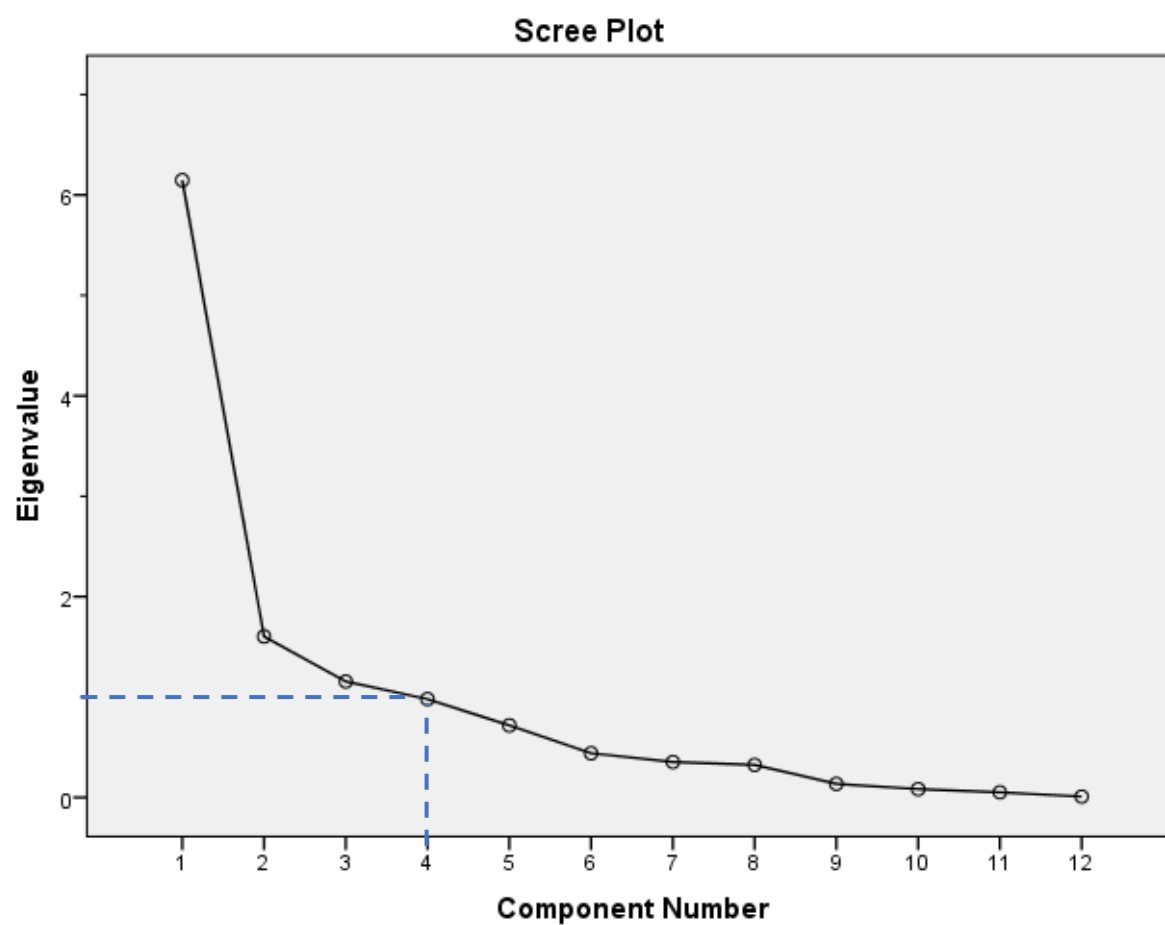


Figure 2. Scree plot of components of average rating scores, psychoacoustical tasks, and duration of training