VALIDATION OF THE SELF-ADMINISTERED VERSION OF THE BATUTA MUSIC PERCEPTION TEST

VALIDAÇÃO DA VERSÃO AUTO ADMINISTRÁVEL DO TESTE DE PERCEPÇÃO MUSICAL BATUTA

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Abstract: Purpose: To assess the reliability of the self-administered version of the BATUTA music perception test, designed to test musical perception in people with hearing impairment. Method: Participants with normal hearing who completed the BATUTA test in person, accompanied by a speech therapist, formed the in-person group (IPG). Participants who self-reported hearing and completed the online version of the test formed the self-administered group (SAG). The Kruskal-Wallis ANOVA test was applied, followed by the Dwass-Steel-Critchlow-Fligner (DSCF) pairwise comparison, to analyze the results for both groups across the rhythm, pitch, and timbre modules. Results: Comparing the IPG (n=51) and SAG (n=91) results showed a significant difference when the BATUTA's timbre module was performed in its self-administered version using a mobile phone and no difference for the rhythm module in any test set. The pairwise comparison among headphones, speakers, computer's integrated speakers, mobile phone speakers, and in-person (controlled conditions) yields a significant difference in the pitch and timbre modules when performed through mobile phone speakers. Conclusion: The use of computer sound ensures the reliable assessment of the rhythm, pitch, and timbre modules of the BATUTA, comparable to its in-person administration in a controlled test environment. The self-administered version of BATUTA is a reliable instrument for assessing the musical perception of individuals with hearing impairment.

Keywords: Music. Hearing impairment. Validation. Test.

Resumo: Objetivo: Avaliar a confiabilidade da versão autoadministrada do teste de percepção musical BATUTA, projetado para testar a percepção musical em pessoas com deficiência auditiva. Método: Participantes com audição normal que completaram o teste BATUTA presencialmente, acompanhados por um fonoaudiólogo, formaram o grupo presencial (GP). Participantes que se autodeclararam com audição normal e completaram a versão online do teste formaram o grupo autoadministrado (GAD). O teste ANOVA de *Kruskal-Wallis* foi aplicado, seguido pela comparação pareada de *Dwass-Steel-Critchlow-Fligner* (DSCF), para analisar os resultados de ambos os grupos nos módulos de ritmo, *pitch* e timbre. Resultados: A comparação dos resultados entre GP (n=51) e GAD (n=91) mostrou uma diferença estatisticamente significativa quando o módulo de timbre do BATUTA foi realizado em sua versão autoadministrada por meio de telefone celular e nenhuma diferença para o módulo de ritmo em qualquer contexto de teste. Quando a comparação é realizada par a par, entre os grupos, sejam eles com fones, com caixas acústicas, com o som do computador, com o som do celular e presencialmente, foi possível demonstrar que há diferença estatisticamente significativa para os resultados dos módulos *pitch* e timbre do BATUTA, quando testados com o som do celular em relação aos demais ambientes. Conclusão: O uso do som de computador é o contexto de aplicação confiável para os módulos de ritmo, *pitch* e timbre do BATUTA, comparável à sua administração presencial em um ambiente de teste controlado. A versão autoadministrada do BATUTA é um instrumento confiável para avaliar a percepção musical de indivíduos com deficiência auditiva.

Palavras-chave: Música. Perda Auditiva. Validação. Tecnologia

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INTRODUCTION

The integration of innovations and technologies in healthcare involves two interrelated areas: one that generates demands and another that develops solutions. Telehealth and technological innovations applied to healthcare have been proposed and implemented for decades. However, it is only recently that this combination has been enhanced by the significant growth of virtual or app-based care in the field of Speech Therapy. This surge is a direct result of the social isolation measures implemented during the pandemic caused by the SARS-CoV-2 virus (Dimer et al., 2020; Santana; Dias; Quintela, 2020).

In addition, audiology is well-acquainted with technological resources. This field has extensive experience with diagnostic equipment and the development of solutions for hearing problems. The efficacy of such developments has been academically validated for self-administered computerized tests, as well as app-based tests for smartphones and tablets (De Swanepoel et al., 2014; Kam et al., 2012; Mahomed et al., 2013).

These resources offer the possibility of rapid diagnosis, particularly in areas with limited healthcare access. The use of portable devices for audiometry can improve access to hearing care for marginalized populations, facilitate early detection of hearing alterations, and enable the implementation of preventive actions (Rourke; Kong; Bromwich, 2016).

Thus, instruments for hearing screening across different populations have had their accuracy validated (Balen et al., 2021; Corry; Sanders; Searchfield, 2017; Larrosa et al., 2015). More recently, wireless headphones have been successfully tested for pure tone audiometry and validated for use with portable device applications in a portable audiometer system (GUO et al., 2021).

Studies of a similar nature have evaluated the reliability of a smartphone application associated with calibrated headphones, yielding results that support its usability in occupational audiometry (Colsman et al., 2020). This method is a simple, accessible, and reliable way for people to learn about their hearing health without the need for formal care (Kam et al., 2012).

Efforts to facilitate the identification and treatment of hearing impairment are justifiable, as they can enhance communication and promote quality of life, especially for individuals who do not seek or lack access to treatment for hearing problems.

Although studies have focused on testing musical perception (Bartov; Most, 2014; Brockmeier et al., 2011; Kim; Lee; Shim, 2020; Kirchberger; RUSSO, 2015; Sahli; Belgin; Uys, 2019; Siedenburg; Goldmann; Van de Par, 2021; Zimmer et al., 2019), highlighting the importance of musicality in entertainment, emotional expression, and health promotion (Cunha, 2016), there are few alternatives for self-administered, low-cost, and easy-to-apply tests in this context.

This study aims to validate the reliability of the self-administered version of the BATUTA music perception test (Simões et al., 2023), which focuses on assessing the music perception of individuals with hearing impairment.

METHOD

The study was approved by the Brazilian ethics committee, according to the substantiated ruling No. 3,581,521. The participants expressed their agreement by signing the Informed Consent Form (ICF)[1].

Instrument

BATUTA[2] is a test developed and validated to assess the musical perception of people with hearing impairment (Simões et al., 2023). It is a computerized test consisting of 35 subtests divided into rhythm, pitch, and timbre modules. Sound samples or musical excerpts, extracted from the Brazilian folklore songbook, are presented on the computer

[1] Translated form Brazilian Portuguese: Termo de Consentimento Livre e Esclarecido (TCLE).
[2] The term BATUTA refers to the conductor's baton used by maestros to lead an orchestra. It symbolizes precision and control in musical performance, which aligns with the test's goal of accurately assessing musical perception abilities. Additionally, *batuta* is a colloquial term in Portuguese meaning something cool or excellent, adding a playful and positive connotation to the name of the test.

in pairs. Participants are required to perform an auditory discrimination task by indicating whether the paired samples are the same or different[3].

The sound samples for the pitch and timbre modules were recorded using real instruments played by professional musicians and, later, converted into MP3 files. Instruments such as the piano, guitar, violin, cello, clarinet, flute, and bassoon were selected after careful discussion between speech therapy and music professionals. The MP3 files were then converted to the MP4 audio and video format to generate the videos that constitute the basis of the test.

The videos present the first sound accompanied by the number 1, followed by a 2-3 second interval of silence with a black screen, and the second sound accompanied by the number 2. The videos for the rhythm module and the melody subtest last 26 seconds; the videos for the harmony subtest, composed of musical chords, last 12 seconds; and the videos for the timbre module last 28 seconds.

After watching the video, which contains no visual stimuli other than the numbers already mentioned, the participant must choose between the alternatives presented, whether the sound is the same or different, which requires an auditory discrimination task.

Participants

The validation process of the self-administered version included the participation of the following groups.

The in-person group (IPG) formed by students, teachers, staff, and patients' companions from a teaching clinic who were invited to take part in the study. The volunteers who agreed to participate underwent conventional pure tone audiometry, with airway research for frequencies of 250 Hz to 8,000 Hz, bilaterally.

The inclusion criteria for the participants in the IPG were: (1) hearing thresholds up to 25 dB HL, bilaterally; (2) minimum age of 18 years; and (3) absence of cognitive

[3] BATUTA music perception test is available in https://www.batuta.pro

alterations. In addition, being or having been an amateur or professional musician, or a music student were exclusion criteria for the IPG.

The self-administered group (SAG) was established through the snowball sampling technique. Initial volunteers were contacts from WhatsApp and Instagram, who received an invitation to take the BATUTA test and were asked to share the invitation further. The sharing via WhatsApp was performed using a link generated by the Google Forms platform. On Instagram, a QR code was shared to access the test, since the latter is a social network that prioritizes visual communication.

The IPG participants agreed to take part and answered, in addition to the test, the validated questions for self-reported hearing loss[4]: (1) Do you feel that you have hearing loss? (2) In general, would you say that your hearing is 'excellent', 'very good', 'good', 'fair', 'poor'? (3) Do you currently think that you 'hear the same way as you did before', 'only the right ear hears less than before', 'only the left ear hears less than before', 'both ears hear less than before'? (Ferrite; Santana; Marshall, 2011).

The inclusion criteria for SAG were: (1) being 18 years of age or older; (2) not being or having been an amateur or professional musician, or a music student; and (3) having answered 'excellent', 'very good' or 'good' to the second question about self-reported hearing loss.

Testing conditions

The participants in the IPG took the BATUTA in a quiet room (Bartov; Most, 2014; Brockmeier et al., 2011; Zimmer et al., 2019), with the stimuli presented in a free field at an intensity of 70 dB A (Sahli; Belgin; Uys, 2019), using a loudspeaker positioned at 0º Azimuth (Zimmer et al., 2019) and 1m away from the participant (Bartov; Most, 2014; Jung et al., 2010; Uys; Van Dijk, 2011). In addition, a speech therapist accompanied the IPG test and controlled the application conditions.

[4] Translated from Brazilian Portuguese.

There was a familiarization session for the participants before testing, which consisted of presenting a sample that was not part of the test set, to ensure the participant's understanding of the concepts of equal and different (Jung et al., 2010).

The SAG participants were instructed in writing, before the test began, to answer the BATUTA in a private and quiet environment, with the intensity of the samples presented at a comfortable audibility level. They also chose and recorded, in the beginning, how the testing would be performed: using a computer or mobile phone, with headphones, external speakers, or the equipment integrated speakers. The SAG participants were free to take the test using any brand and model of equipment.

The data were analyzed using the Jamovi statistical software (version 1.6). Data normality was assessed using the Shapiro-Wilk test, and due to the lack of normality, the non-parametric Kruskal-Wallis test was chosen to compare the groups. For multiple comparisons, the Dwass-Steel-Critchlow-Fligner (DSCF) post hoc test was used. The median and interquartile range were adopted as measures of central tendency and dispersion, respectively, due to their robustness against skewed distributions. The rhythm, pitch, timbre, and total modules were analyzed in both controlled test environments and self-administered settings via computer or mobile phone.

RESULTS

The characterization of the 51 participants who met the inclusion criteria to join the IPG and the 91 SAG participants, after excluding those who self-reported regular hearing, are shown in Table 1.

Table 1. In-person and Self-administered group profiling (n=142)

	n	**Gender%**		**Age%**	
		Female	Male	Mean	Standard Deviation
IPG	51	70,6	29,4	32,31	10,96
SAG	91	72,5	27,5	40,42	9,89

The answers given by the participants of the IPG and SAG were tabulated in Microsoft Excel (version 16.0). Correct answers were assigned a value of 1 (one) and incorrect answers were assigned a value of 0 (zero). SAG was subdivided into whether the test was taken using a mobile phone or a computer and the samples were treated independently.

Table 2 shows the descriptive statistics of the 142 participants' correct answers to the 35 BATUTA subtests carried out in a controlled and self-administered environment, either by computer or mobile phone. The minimum values for all the modules stand out when the test was performed using a mobile phone, with the lowest number of correct answers in this form of application.

Table 2. Descriptive statistics of the participants' correct answers to the 35 samples across the different settings. (n=142)

	n	**Sound Samples**	**Setting**	**Mode**	**Median**	**Minimum**	**Maximum**
Rhythm	72	9	Mobile phone	9	9	5	9
	19	9	Computer	9	9	7	9
	51	9	In-person	9	9	6	9
Pitch	72	16	Mobile phone	16	15	7	16
	19	16	Computer	16	15	8	16
	51	16	In-person	16	16	11	16
Timbre	72	10	Mobile phone	10	10	4	10
	19	10	Computer	10	10	8	10
	51	10	In-person	10	10	8	10
Total	72	35	Mobile phone	35	35	21	35
	19	35	Computer	35	34	26	35
	51	35	In-person	35	35	29	35

The comparison between the groups for the rhythm, pitch, timbre, and total modules, in the test environments with controlled conditions, and in the self-administered option carried out on the computer or mobile device is shown in Table 3. Concerning the correct answers for the timbre and total modules, the results of the mobile phone test were different from those obtained when the participants answered the BATUTA on the computer or in controlled conditions, with minimum values considerably lower than the others.

Table 3. Comparison between IPG and SAG results across the different settings. (n=142)

	Rhythm	Pitch	Timbre	Total
	Median (IQR)	**Median (IQR)**	**Median (IQR)**	**Mediana (IQR)**
Mobile phone	9 (1)^{A}	15 (2.2)^{A}	10 (1)^{A}	33 (4)^{A}
Computer	9 (0)^{A}	15 (1.5)^{A}	10 (1)^{AB}	34 (1.5)^{AB}
Controlled conditions	9 (0)^{A}	16 (1)^{A}	10 (1)^{B}	34 (3)^{B}

Kruskal-Wallis ANOVA test, with post hoc pairwise comparisons using the Dwass-Steel-Critchlow-Fligner (DSCF) procedure; different letters within the same column indicate difference ($p<0.05$).
Legend: IQR=Interquartile Range

When the comparison included the use of headphones and external speakers, as well as computer's integrated speakers, mobile phone speakers, and the controlled conditions version, it was possible to identify a difference when mobile phone speakers come into play. The latter is the worst BATUTA testing condition for both pitch and timbre, with the total influenced by the measurements of these two modules (Table 4).

Table 4. Comparison between IPG and SAG results regarding the different sound sources. (n=142)

	Rhythm	Pitch	Timbre	Total
	Median (IQR)	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**
Headphones	9 (1)^{A}	15 (1.7)^{AB}	10 (0)^{AB}	34 (1)^{AB}
External speakers	9 (0)^{A}	15 (2)^{AB}	10 (0.5)^{AB}	34 (2)^{AB}
Computer's Integrated speakers	9 (0.75)^{A}	15.5 (1)^{AB}	10 (0)^{AB}	34 (3)^{AB}
Controlled Conditions	9 (1)^{A}	16 (1)^{A}	10 (0)^{A}	34 (3)^{A}
Mobile phone speakers	8 (2)^{A}	14.5 (3)^{B}	10 (1)^{B}	31.5 (5)^{B}

Kruskal-Wallis ANOVA test, with post hoc pairwise comparisons using the Dwass-Steel-Critchlow-Fligner (DSCF) procedure; different letters within the same column indicate difference ($p< 0.05$).
Legend: IQR=Interquartile Range

It is worth considering that when the BATUTA was performed using headphones or external speakers, there was no difference compared to testing under controlled conditions. This suggests that the test can be effectively applied in its self-administered version.

DISCUSSION

The results indicated that participants' performance on the BATUTA timbre module was significantly worse when using a mobile phone compared to a computer or when the test was administered in the presence of a speech therapist.

When a pairwise comparison was made between the groups—whether using headphones, external speakers, computer's integrated speakers, mobile phone speakers, or under controlled test conditions—it was evident that mobile phone speakers presented the most challenging condition for answering the BATUTA's pitch and timbre modules.

Regarding the rhythm module, no significant differences were found when comparing the conditions based on the sound source or when pairing the groups. This result is not surprising, as rhythm is a temporal aspect of music and thus is less influenced by the quality of the sound source (Prevoteau; Chen; Lalwani, 2018).

On the other hand, pitch is a subjective musical attribute and is a spectral element of music. As it is closely related to melody and harmony, pitch is a component of music whose perception is influenced by the frequency range produced by the sound source. The impact of the different conditions on the BATUTA test reflected this specificity since different sound sources reach different frequency ranges (Sorrentino et al., 2020).

Since timbre is a combination of the temporal and spectral elements of music, it reflects the entire complexity of the musical sound, as it covers a wide range of frequencies and rhythms. Considering the uniqueness of music, expressed by more intense sounds and a more varied frequency range than that recorded in speech sounds, it is possible to assume that the results in Tables 2 and 3 represent the difference in perception of music when reproduced by different sound sources (Chasin & Hockley, 2018; Prevoteau et al., 2018; Riley et al., 2018).

In this scenario, it is possible to conclude that the BATUTA rhythm module can be carried out, in its self-administered version, with any of the conditions tested. In addition, the use of mobile phone speakers is contraindicated for testing the pitch and timbre modules, given that the difference between the performance of the SAG compared to the IPG was significant, with worse results for the former, as described in Table 2.

Conversely, when the test was carried out using mobile phones integrated with headphones, no significant differences were found in the comparison between the groups for the pitch and timbre modules, as described in Table 4. This indicates that headphones plugged into the mobile phone produce better quality sound.

Therefore, it is interesting to examine the implications of using headphones in the analysis results. Anecdotal evidence suggests that headphones, commonly used in daily life to carry music everywhere, can enhance the music appreciation experience by isolating external sounds.

It should be noted that BATUTA was primarily developed to test the musical perception of people with hearing impairment who use hearing aids (HAs). These individuals typically do not use headphones due to the difficulty of combining the two devices. Therefore, despite the potential improvement in the quality of musical perception when using headphones with a mobile phone during the BATUTA test, this method is not very feasible for this audience. The simultaneous use of HAs and headphones is impractical, except in cases where the headphones are connected to the HAs via Bluetooth.

Alternatively, the self-administered version of BATUTA, when applied through mobile phones with headphones, can be used to analyze the musical perception of people with hearing impairment (HI) who do not use HA.

Additionally, it should be noted that there are no established tests to set a standard of normality for assessing the musical perception of people with hearing impairment, and the self-administered version of BATUTA is no exception. Consequently, repeated testing across different scenarios, between groups and within individuals, as well as various other research possibilities, can help establish parameters for its systematic use. This applies to both hearing aid (HA) and cochlear implant (CI) users, as well as in clinical practice

CONCLUSION

The self-administered version of BATUTA is a reliable, easy-to-use and low-cost instrument that can be used to assess the musical perception of people with hearing impairment who wear hearing aids.

The results indicated that using a computer, with or without headphones and with or without external speakers (integrated sound), are the testing conditions that effectively evaluate the rhythm, pitch, and timbre modules of BATUTA. They present similar results to its in-person administration when accompanied by a speech therapist, under controlled testing conditions, and are, therefore, the most recommended possibilities for the intended audience.

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