REVISTA DESIGN & TECNOLOGIA
ISSN: 2178-1974
2022, Vol. 13, No. 26
DOI 10.23972/det2023iss26pp92-102

PGDESIGN
www.pgdesign.ufrgs.br

Binaural hearing scale: assessment validation tool for satisfaction and emotion considering people with visual impairment

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ABSTRACT

Many barriers are still observed in the interaction between the visually impaired person and mobile applications. It is debatable that part of the problem stems from that accessibility evaluations do not necessarily include users participation and the study and solution proposal for these problems require not only requirements conformity, but requests user active involvement in the design or research processes. Therefore, a tool to collect data on satisfaction and emotions was developed - Binaural Hearing Scale (3D audio) -, whose purpose is to expand the participation of people with visual impairment in user tests in digital interface assessment. In this article, the following question was addressed: What is the reliability and validity of the binaural hearing scale (3D audio) to assess the satisfaction of people with visual impairment in usability tests? The objective of this article is to validate the prototype of the Binaural Hearing Scale Tool (3D audio) through Cronbach's Alpha and the survey of the perception of people with visual impairment regarding its relevance and effectiveness. The results showed that the participants had experience using these devices for a long time however, despite the experience, they still face several usability problems which directly affect performance in conducting the tasks. As a result of the validation, interaction with the 3D hearing aid was deemed satisfactory. And its consistency and acceptable reliability. For people with visual impairment, the tool gives the opportunity to participate in usability assessments and other tests that use perception scales. The tool allows the participation of people with and without visual impairment both in person and remotely. For developers, it presents itself as an option for testing interfaces or products considering the participation of people with visual impairment.

PALAVRAS-CHAVE

Visual impairment;
Usability;
Satisfaction;
Binaural Audio

Escala auditiva binaural: validação de uma ferramenta de avaliação da satisfação e das emoções considerando as pessoas com deficiência visual

RESUMO

Muitas barreiras ainda são observadas na interação entre a pessoa com deficiência visual e os aplicativos móveis. É discutível que parte do problema decorre do fato de que as avaliações de acessibilidade não necessariamente incluem a participação dos usuários e o estudo e a proposta de solução para esses problemas exigem não apenas a conformidade dos requisitos, mas também o envolvimento ativo do usuário nos processos de projeto ou pesquisa. Portanto, foi desenvolvida uma ferramenta de coleta de dados da satisfação e das emoções - Escala auditiva binaural (áudio 3D) -, cuja finalidade é expandir a participação de pessoas com deficiências visuais em testes com usuários na avaliação de interfaces digitais. Neste estudo abordou-se a seguinte questão: Qual a confiabilidade e a validade da escala auditiva binaural (áudio 3d) para avaliar a satisfação de pessoas com deficiência visual em testes de usabilidade? O objetivo deste artigo é validar o protótipo de Ferramenta Escala auditiva binaural (áudio 3d) por intermédio do Alfa de Cronbach e do levantamento da percepção de pessoas com deficiência visual quanto à sua relevância e eficácia. Os resultados mostraram que os participantes já tinham experiência no uso desses dispositivos há muito tempo, porém, apesar da experiência, ainda enfrentam diversos problemas de usabilidade que afetam diretamente o desempenho na condução das tarefas. Como resultado da validação, a interação com a ferramenta foi considerada satisfatória. E sua consistência e confiabilidade aceitável. Para pessoas com deficiência visual, a ferramenta desenvolvida dá oportunidade de participar de avaliações de usabilidade e demais testes que utilizam escalas de percepção visual. A ferramenta permite a participação de pessoas com e sem deficiência visual tanto de forma presencial, quanto de forma remota. Para desenvolvedores apresenta-se como uma opção para testes de interfaces ou produtos considerando a participação de pessoas com deficiência visual.

KEYWORDS

Deficiência visual;
Satisfação;
Usabilidade;
Audio binaural

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1. INTRODUCTION

Vision is the most useful since for processing specific information (PIGEON; MARIN-LAMELLET, 2015). Degrees of vision involve a vast spectrum of possibilities that range from total blindness to perfect vision. The expression 'visual impairment' ranges from blindness to low vision (GIL, 2000). According to 2010 IBGE data, there are more than 6.5 million people in Brazil with some sort of visual impairment: 528,624 people are incapable of seeing (blind); 6,056,654 people have low vision (great and permanent difficulty seeing); another 29 million people stated that they have some form of permanent vision problem even though they use glasses or contact lenses (IBGE, 2010). Currently, it has been estimated that blindness affects 39 people around the world and that 246 million have suffer from severe or moderate loss of vision (OTTAIANO et al, 2019).

In a modern and computerized society, access to visual information has become a central need for all types of people, including blind and visually impaired people (LAHIB et al., 2018). When it comes to interacting with digital media, Filho and Santos (2015) address the increased use of mobile devices by blind people. Considering that these people have increasing access to the digital world, it is necessary to understand how they feel in relation to interfaces in order to develop products that are inviting to use and that are used independently and regularly.

In the opinion of Gomez and Sandnes (2012), technological advances have helped reduced the barriers that involve blind people and their participation in society. One issue to be considered with public awareness is satisfaction, which according to Tullis and Albert (2008), is related to what the user says or thinks about the quality of their interaction with the product, especially important when people have alternatives such as with technological products (applications, smartphones, tablets, computers and others).

Therefore, it is understood that the participation of people with visual impairment in user tests is also essential to understand their needs, and the level of satisfaction regarding the interaction with digital products and systems, since interface assessments are essential to offer better interaction with the system, because as Cybis, et al (2010) claim, users are most knowledgeable about the system in a real context, so their involvement in the project is quite natural.

Considering user participation in these assessments, it is also essential to include people with visual impairment since digital accessibility is a fundamental and inseparable principle in usability studies. The right to the elimination of architectural barriers, access to communication, physical access, appropriate programs, equipment, content and the presentation of information in different formats must be a reality for people with visual impairment (CAMBIAGHI, 2012). Information access technologies save and shorten the time needed for certain information.

Gomez and Sandnes (2012) believe the physical and digital world challenge blind people. These authors warn that there are several studies dedicated to revealing and interpreting these worlds, transforming them into audible speech, and converting visual images and human orientation into sounds. Pigeon and Marin-Lamellet (2015) add that there is already a longstanding discussion that leads to the possibility that blind people compensate for the lack of vision through improvements in tactile and hearing sensitivity.

Considering these issues, Trinta (2020) sought to develop a tool that would enable people with visual impairment to record their emotions when using digital applications, expanding the participation of in usability tests. The tool developed by Trinta (2020) used analogously to vision, which according to Berg (2017) is hearing. Thus, the binaural 3D audio format was then used in the development of a hearing satisfaction scale – 3D hearing aid (TRINTA, 2020) – to record satisfaction, aiming to expand this audience in user tests.

According to Nunes (2011), binaural sound has the characteristic of allowing the listener to identify and distinguish the quantity and location of sound sources in an environment. If recorded correctly, it accurately reproduces any type of environment, transporting the listener almost perfectly into the recorded situation. It thus refers to a resource that provides the listener with a sense of space and ideas of distances and locations in space, both horizontally and vertically.

It should be considered that visually impaired people perform better in auditory processing activities, such as sound localization and lateralization (DIAS; PEREIRA, 2008). However, the process of recording the binaural sound is more refined and exceeds the laterality of stereo sound, which makes it possible to differentiate horizontal positions from left-right.

Binaural audio is made up of a left and right ear signal that can be directly reproduced by headphones. According to Nicol (2014), these signals can be recorded directly, using, for example, a dummy head or in-ear microphones, or synthesized using individual or non-individual HRTF (head, related, transfer, functions, or head-related transfer functions) filters.

By understanding that all users, including those with different visual levels, have the right to use digital interfaces in an effective, satisfactory, comfortable and understandable way, this work seeks to validate, through Cronbach's Alpha, the 3D audio tool prototype of data collection on satisfaction in usability tests considering people with visual impairment.

2. THEORETICAL REFERENCE

Darin et al. (2022) points out that there are several studies that have analyzed usability assessment techniques in interfaces used by blind people, among them are the works of Fukuda et al., 2005; Lee and Lee, 2019; Miao et al., 2016; Petrie and Kheir, 2007; Raisamo et al., 2006. The authors comment that there is a need to adapt satisfaction assessment methods and instruments to fit the context of blind people more effectively.

2.1 Satisfaction assessment with verbal tools

Verbal tools assess the subjective feelings of users' emotions through self-reports, which according to Desmet (2004, p. 5) is the "conscious perception of one's emotional state, the subjective emotional experience". The feelings of happiness or inspiration are examples of these feelings.

Desmet (2004) states that the tools commonly used to assess these feelings involve verbal protocols, rating scales so that users can describe their emotions. Furthermore, according to the author, the greatest advantages of verbal tools are that rating scales can be used for any kind of emotion and can also determine mixed emotions. Whereas the downside of these tools is that they rely on a language to differentiate emotions. The language consists of words that translate what is being thought and felt, and in this translation process, distortions of what was experienced by the user can occur, thus losing the quality of the collected elements.

Another disadvantage of this kind of verbal tool is that when used in diverse cultures, the literal translation of words that express the emotions experienced from one language to

another is sometimes not possible (DESMET, 2004; BERG, 2017).

The knowledge of emotions can be evaluated by the user's degree of satisfaction with the product. Thus, some verbal tools can be applied for this purpose, such as SUS – System Usability Scale tool.

SUS is a tool created by John Brooke in 1986, which aims to facilitate and speed up the subjective usability assessment of products and systems in a reliable, practical and economical way. It is based on a simple Likert scale composed of ten statements (five positive and five negative) which give a total view of the subjective usability assessments. Each statement is composed of a single sentence, such as, "I found the system easy to use" and it has a five-point scale, ranging from Strongly Disagree (1) to Strongly Agree (5) (BROOKE, 2014; PERES et al, 2013). The final scoring system of this scale is amazingly simple – from 0 to 100 – and quite dependable.

SUS has a higher degree of reliability in relation to other questionnaires, as stated by Sauro (2016), such as the QUIS (Question for User Interface Satisfaction). Also, according to the authors, several reliability assessments of SUS were performed, in one, based on 77 cases studies, there was a 0.85. reliability result.

In a more recent study, involving 2,324 cases, it was noted that SUS was extremely dependable, reaching 0.91 (BANGOR et al., 2008). Also, in this last study, several types of interfaces were analyzed, and it was concluded that there was a small but relevant correlation between age groups and SUS results and no correlation in relation to gender.

Considering the context of people with visual impairment, Trinta (2020) adapted the SUS tool to Braille in order to verify the possibility of using this tool to analyze interfaces by people with visual impairment and the results indicated that most participants found the tool long, also stated that they found it hard to navigate the document - finding the questions and the reading flow. Participants assessed that the SUS questionnaire assesses satisfaction with the tested product well, but they did not consider it very accessible since they reported that many visually impaired people are not literate or used to reading Braille, which would be a barrier when applying the questionnaire. to these people.

2.2 Satisfaction assessment through hearing aids

In order to serve the visually impaired audience based on their emotions in usability tests, Berg (2017) developed the onomatopoeic tool, which uses sounds in onomatopoeic format to identify human emotions. For this, Berg (2017) first identified which senses were similar to vision in people with visual impairment, having hearing and touch as a response, with hearing being the sense chosen to compose the tool. This is because the author found that tactile tools are very restrictive since people with different visual skills do not have image libraries formed and do not recognize facial expressions. Therefore, the hearing option was used as the prototype since it also requires few resources and experience for the application.

Berg (2017) considered using words in the tool, as used in the circumplex model of affect, however, he considered that the use of words does not convey the necessary emotion. Thus, the hypothesis was raised that onomatopoeias can be used to measure emotions in usability tests. In this way, the prototype of the onomatopoeic tool was developed based on EMOCARD, a non-verbal tool chosen, according to the author's criteria because it is easy to apply and analyze, be used in usability tests, identify emotions among other aspects. The Emocard is composed of 16 illustrated cards that represent various types of emotions. It is applied after the usability test, in which the user can point out which card best represents their emotion when using the product being evaluated (DESMET et al, 2001).

These expressions were taken to the studio to be recorded and then pilot tested with visually impaired users. In this test, the author asked which onomatopoeia represented the indicated emotion. The volunteers were allowed to listen to the onomatopoeias several times until they decided which one was the most suitable for each emotion. The options were recorded on a scale from 0 to 7 so that the participants could indicate their choice by the number corresponding to the chosen onomatopoeia. Subsequently, the author divided into two groups and performed a usability test to validate the tool, whose task was to search for news about people with visual impairment.

A second tool, the Circumplex Model of Affection, was chosen to compare the valences when using onomatopoeic prototype. Thus, each person evaluated their experience either with the onomatopoeic tool or with the circumplex model of affect. To analyze the results, Berg (2017) compared the valence of the two tools and the calculation of x^2 in order to compare answer similarity. χ^2 evaluates whether two or more samples differ with respect to a variable. The samples should not be related, making it possible to verify if they differ by chance, developing a certain pattern. This test verifies the hypothesis that a given data frequency follows a theoretical frequency. Finally, after analyzing calculation and valence, the author concluded that the two tools are similar, therefore, he answered the hypothesis: self-reporting tools with onomatopoeias of human emotions can be similar to verbal tools in people with visual impairment.

Trinta (2020) assessed the onomatopoeic tool and found that the participants considered this tool different and extremely interesting. They said they understood that the emotions at hand were identifiable. Although some of them were confused at first, they also claimed that they understood the onomatopoeias.

Also, according to the author, some options were very similar for most participants, which was confusing when identifying, thus causing different interpretations. Some participants felt that the tool had too many options (8) which could be confusing when choosing. They also found the onomatopoeias "strange" or meaningless, and that this tool does not clearly translate the emotions felt because they could not identify what they were expressing in some of them. They also considered the tool very artificial and not very dynamic because it did not transmit an auditory human emotion, and requires a few modifications (TRINTA, 2020).

Considering these results, Trinta (2020) developed a tool with a binaural 3D hearing format, with the purpose of creating a sound scale since this format enables perception of the origin and direction of the sound source in space. For this, the 3D tool creation process followed the steps of Participatory Design Methodology. It is divided into three steps as Spinuzzi (2005) states: initial exploration of research, discovery and prototyping. All steps were developed by visually impaired people. Trinta (2020) added the last step in order to test the tool with real users, naming it pre-validation.

2.2.1 Binaural Hearing Scale Tool (3D audio)

The Binaural Hearing Scale Tool (3D audio), like the onomatopoeic, is a prototype resulting from an academic study carried out by researcher Ana Paula Trinta in 2020. In this research, the author uses a binaural 3D hearing format, in order to create a sound scale since this format makes it possible to perceive the origin and direction of the sound source in space (https://youtu.be/kuTXTDvum8I).

In the first methodological phase (initial study exploration), the author investigated the main daily obstacles encountered by person with disability. For this, a meeting was held in the form of a conversation circle called Ciranda Inclusiva (TRINTA, 2021) with person with disability, people involved in the cause for inclusion and students and teachers from the <removed for blind review>. Many participants had the opportunity to report their difficulties and expectations for improvements.

In the second part of the first methodological phase, interviews were carried out with different groups, all of whom were blind or low vision. The first group was formed by students from the <removed for blind review> School for the Blind, the second was formed by students from the Center for Social Sciences of the <removed for blind review>. As a result of the interviews, the main activities carried out by the participants were identified, as well as their main difficulties, accessibility resources used, time of use, and how this audience deals with touchscreens.

In the second stage, Discovery, two tools were tested to collect data on satisfaction and emotions of blind and low vision users: the SUS (System Usability Scale) questionnaire – in an expanded format, for people with low vision and, transcribed into Braille for the blind – and the onomatopoeic Tool (BERG, 2017). Trinta (2020) held workshops with both groups, in which users performed some activities established by the researcher in two apps. After completing the tasks, participants evaluated their experience using the two tools.

As the main result of this stage, participants considered the onomatopoeic tool more accessible for people with visual impairment since it is in the hearing format. However, most could not interpret the onomatopoeias, nor understand them as expressions of emotions, considering them too confusing and artificial. So, they suggested that onomatopoeias be replaced by phrases, words and expressions so that emotions could be identified more easily.

This consideration was fundamental for creating the 3D hearing aid, starting the third phase, prototyping. The author then collected suggestions for phrases and expressions from the volunteers. For this, satisfaction and dissatisfaction with the apps were simulated so that participants could suggest the expressions they would use in each of them.

After collecting the suggestions, the author made them available on an online questionnaire so that more people (with and without visual impairment) could choose which expressions best represented the emotions in each situation. The result of this questionnaire was formed by the most voted expressions for each situation, divided into 4 models of expression sets and taken to the recording studio.

The recording included a visually impaired person. After recording, the researcher tested the models with visually impaired participants. The most voted expressions made up the official phototype expression. These expressions were again taken to the recording studio where the sound spatialization process was carried out, transforming the sound into a binaural 3D format. The sequence of expressions chosen that form the 3D hearing scale was then schematized by Trinta (2020) according to the distance from the sound sources and azimuth angles (Figure 1) and; elevation angles (Figure 1).

Finally, the author conducted a pre-validation of the 3D hearing aid with 3 visually impaired people. Applications that people used infrequently were used for user tests, and later the participants evaluated their experiences using the 3D tool.

As a main result, all participants explained that the tool is very accessible for blind and low vision people, and that expressions are very easily identified, and voice intonation helped identify emotions. In addition, most observed that the sound sources formed a sound scale which started on the left side with the negative options and ended on the right side with the positive options (TRINTA, 2020).

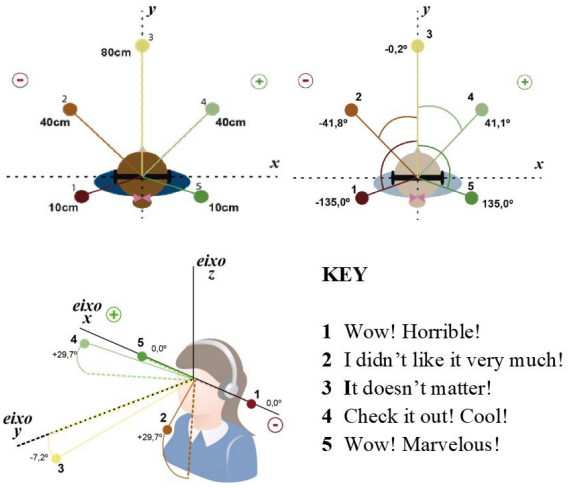


Figure 1 Above, separation from the source and azimuth angles. Below, elevation angles and key. (Source: Adapted from Trinta, 2020)

It is important to note that the pre-validation carried out by Trinta (2020) included participants who participated in the tool development so it is not known whether this factor may have influenced the results. Thus, this research aims to contribute so that the 3D tool can be validated and verify its reliability with the purpose of providing a tool for collecting data related to satisfaction regarding use, and allowing greater participation by people with visual impairment in user tests.

3. RESEARCH METHODS AND TECHNIQUES

This research is exploratory in nature. Exploratory research proposes greater knowledge of the problem in order to make it more understandable and its main objective is to improve ideas or discovery intuitions (GIL, 2002). For this, the research this work was conducted in 4 stages, as presented in the following subtopic.

3.1 Research stages and procedures

This research was developed in accordance with the stages shown in Figure 2.

In step 1, the Term of Free and Informed Consent was first presented to the participants, in which their authorization to participate in the research was requested in addition to stating study objectives, clarifying research procedures, presenting research protocols and the forms of volunteer participation.

The participants were informed about the possible discomforts and risks of their participation in the research, which were at least, in addition to the expected benefits of participation and presentation of the measures and cautions to be used to reduce discomforts, such as previous clarifications, the guarantee to the participants the freedom to refuse to participate or withdraw their consent, at any stage of the research, the maintenance of secrecy and privacy of participants. Participants had no expenses to participate in the study. As these are people with visual impairments, the term was read and explained in the presence of the participants, and then the participant consented to their participation by audio recording.

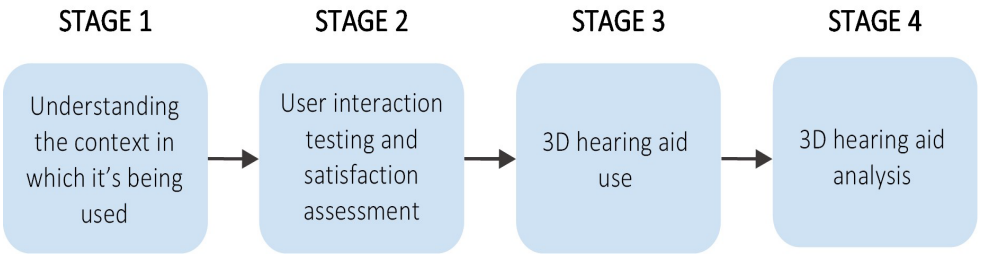


Figure 2 Research stage. (Source: created by the authors,2022).

After confirmation of acceptance and question clarification, a protocol was applied for identification to collect personal information, data on their disability and on smartphone use. A semi-structured interview was also carried out in order to know about patients' smartphone use, their impressions, difficulties and barriers they find in the interaction, if they need help from other people to perform the tasks and if they feel satisfied using he interfaces. After this analysis, the applications were chosen for testing with the 3D hearing aid through an interaction test.

In step 2, participants were invited to use the 3D hearing aid through a user test on two apps, a local supermarket or an e-commerce app. This was due to the fact that three participants were unable to download the e-commerce application so they used the local supermarket app to perform the same task.

After using it, they assessed their satisfaction with their 3D tool interaction. The task to be performed on the local supermarket app was for participants to add two products to their shopping list – one for grocery and one for cleaning – of their choice. In the e-commerce application, the task was for participants to place a product in the shopping cart. After performing the tasks on the apps, each participant used a headphone and listened to the 3D tool. Then, the researcher asked the question: Which option did you hear on the 3D tool that you found closest to what you felt when using the application? To assess the application used, the participant informed which option they understood to be closest to the emotion they felt when performing the task.

After this stage, stage 3 began, in which a semi-structured interview was conducted about using the tool. To assess the level of user satisfaction with the 3D hearing aid, a questionnaire was applied. The questionnaire consisted of 11 questions that investigated how easy the tool is, its suitability for the proposed hearing scale and its compatibility regarding expressions used with the emotions felt through a Likert scale. Finally, in stage 4, to assess the reliability and validity of the 3D hearing aid, data analysis was performed using Cronbach's Alpha coefficient.

These steps were performed at the agreed date and time with each participant. Two cell phones were used in the interviews, one for recording the audios and another for photos, in addition to a laptop for reproducing the 3D tool.

3.2 Research participants

Research participants were divided into 3 groups defined as "ESCEMA group", "UFMA group", "ASDEVIMA group" and one person without a group. The ESCEMA group is formed by volunteers from the Maranhão School for the Blind, which offers education from kindergarten to 9th grade, for children, youth and adults.

The UFMA group is formed by students from several courses at the Federal University of Maranhão, and the ASDEVIMA group is formed by volunteers from the Visually Impaired Association of Maranhão, which offers provides the service of making menus in Braille for the blind and people with low vision and also signage in Braille for concert halls, events, restaurants, bars, shopping malls, cafeterias and other public places patronized by people with visual impairment.

3.3 Sample size

For usability tests, Tullis and Albert (2008) suggest a number of participants ranging from 4 to 10 people. Although in this research the usability test was not carried out in full since only the satisfaction metric was measured it was decided to take into account this minimum number of participants.

In the first group, ESCEMA, 2 volunteer was recruited to collaborate with the work. In the second group, UFMA, three students agreed to participate in the research. In the third group, 2 people participated in the research. The total number of participants was 07 (seven) people, with no exclusion criteria regarding gender or area of knowledge.

3.4 Validation tool with Cronbach's Alpha

Spector (1992) states that a good scale must have good psychometric properties, that is, they ensure reliability and validity which the scale measures consistently. One way to check if a scale is dependable (time) and if it measures what was proposed (validity) is through Cronbach's Alpha.

Cronbach's Alpha coefficient (α) determines the reliability of the applied questionnaires, that is, their ability to be consistent. Any reference to a measurement's reliability generates reference to Cronbach's Alpha index (MAROCO; GARCIA-MARQUES, 2006).

The reliability of a measurement refers to its ability to be consistent. For example, if a measuring instrument always gives the same results (data) when structurally used on the same targets, we can be confident that the measurement is dependable. However, we say to a greater or lesser degree because every measurement is subject to error. In this way, the reliability that is observed in the data is an estimated.

Any measure (X) taken by a scale or test by an individual, always has two additive elements (PASQUALI, 2003): the true result (score), ability, classification or measure (τ) of the object and the measurement error of the attribute. or object capacity (εx):

$$X = \tau + \varepsilon_x \quad (1)$$

"Error" is the variability noted in the measurement process of the same object. The absence of error is "consistency". And consistency is the essential term to determine reliability (MAROCO; GARCIA-MARQUES, 2006).

According to data found in the literature (NUNNALLY; BERNSTEIN, 1994; NICHOLS, 1999) a good Cronbach's Alpha index (ranging from 0 to 1) must be greater than 0.7 (α > 0.7). However, α > 0.6 is an acceptable index (MAROCO; GARCIAMARQUES, 2006; LANDIS; KOCH, 1977). Cronbach's Alpha is measured using the formula α= (number of items/1 (–) number of items) x 1 – (sum of item variance /variance of sum of subjects' points).

Table 1 Consistency level according to alpha value (LANDIS; KOCH, 1977).

Cronbach's Alpha value	Consistency Level
Greater than 0.8	Almost perfect
0.8 to 0.61	Substantial
0.6 to 0.41	Moderate
0.4 to 0.21	Reasonable
Less than 0.21	Low

(Source: adapted from Landis and Koch, 1977).

Alpha values that determine consistency levels as shown in Table 1 and Table 2.

Table 2 Consistency level according to alpha value (MAROCO; GARCIA-MARQUES, 2006).

Cronbach's Alpha value	Consistency Level
Greater than 0.7	Good
0.7 to 0.6	Acceptable
0.59 to 0.5	Questionable
Less than 0.5	Unacceptable

(Source: adapted from Maroco and Garcia-Marques, 2006).

3.5 Research location

The research was carried out in different environments and the meetings were scheduled in the places indicated by each participant.

Three volunteers preferred their own homes for data collection. Another three chose their workplaces (ESCEMA and ASDEVIMA) and one volunteer booked an appointment at one of the local shopping malls (Figure 3).



Figure 3 ASDEVIMA room, one of the participants' homes and the food court in a mall. (Source: created by the authors, 2022).

4. RESULTS

Of the 7 (seven) people who participated, there were more men (5) than women (2). The age group ranged from 18 to 45 years old. Of the seven participants, three were students and four worked. Regarding disability, 4 (four) declared themselves blind - one congenital and 3 (three) acquired - and 3 (three) declared themselves low vision – two congenital and one acquired. Six of the seven participants claimed they know how to read Braille.

4.1 Interviews

The interviews made it possible to understand how the participants interacted with smartphones, which digital platforms they used the most, as well as their difficulties and the learning process. The main results related to the interview are summarized in Table 4.

It was found that the participants had experience using these devices for a long time (at least 4 years), corroborating what Filho and Santos (2015) address about these people having increased access to the digital world. In addition to the use of -smartphones¬, the use of other devices was also highlighted - such as computers and tablets - for use in academic work or schools since they require more agility for typing and have a larger interface. Smartphones are mostly used for social networks, google searches, news and some also claimed to use them for banking services.

Among the difficulties identified by the participants are problems with the screen reader and system feedback. Regarding the screen reader, the complaint was that it does not describe images, which makes it impossible for the blind to have access to what is being presented.

Table 4 Synthesis of interview results.

Synthesis of interview results	
Time of use	At least 4 years
Main accessibility resources	Blind users: screen reader; Low Vision: font enlargement and zoom.
Main activities performed	Calls and social networks (WhatsApp, Facebook, Instagram, YouTube); Google search; bank services; radio TV
Main barriers	Blind users: lack of image descriptions; lack of feedback. Low Vision: small print.
Autonomy	Use it independently; Only need help when using new cell phones or apps for banking services
Touchscreen	Blind and low vision users declare that they don't have any difficulty using smartphones with touchscreens.
Final considerations	They use other devices with digital interfaces (tablets and desktop computers); Blind and low vision users state that they need help with some new apps and banking services. Also, when using new cell phones, they need help activating the device.

(Source: created by the authors).

In terms of feedback, there is too little and it's difficult to understand. According to Goss (2015), many problems are identified when reading interfaces that are not developed within the accessibility standards necessary to interact with

visually impaired people. This lack of accessibility can be overcome by following good programming techniques in app development, which can enable screen readers to correctly read graphic elements (DAMASCENO et al, 2017).

The other difficulty addressed by the participants was feedback. The lack of system response leaves users confused about their status, increasing the time to complete tasks, or even making it impossible for users to complete them. This lack of feedback can be seen as a usability problem, which encompasses actions that leave the user with no direction and that make it impossible to finish the task (TULLIS; ALBERT, 2008). So, the most appropriate thing is that the system offers the necessary answers so that users can continue their activities.

Another difficulty raised was in relation to learning the system. Although they assured that they needed help from third parties at the beginning, all said that they currently interact independently, except in cases such as with new apps or help with banking operations. Finally, everyone said they had no problems with touchscreens.

We emphasize here the great importance of research in this area. It is observed the enormous contribution that the digital space can provide to people with visual impairment through more propitious environments for the social inclusion of these people, with the use of tools that help them not access. According to Gonçalves et al. (2011), technological advances are not just less comforting, but they play an important role and are increasingly active in the daily lives of people.

Among the reports presented, the comments made in relation to the difficulties encountered during the use of these devices were of paramount importance. And that people with visual impairment still face several usability problems which directly affect performance in conducting the tasks, that is, the usability metrics: effectiveness, efficiency and satisfaction defined by Nielsen (1994) and the other authors.

4.2 Stage 2 – User interaction test and satisfaction assessment

Each participant listened to the tool and then informed which option they thought was closest to the emotion felt when finishing the task on the supermarket or e-commerce app. Some participants requested to repeat the audio at least two times to confirm their choices. The results regarding app analysis by way of the 3D hearing aid are shown in Figure 4.

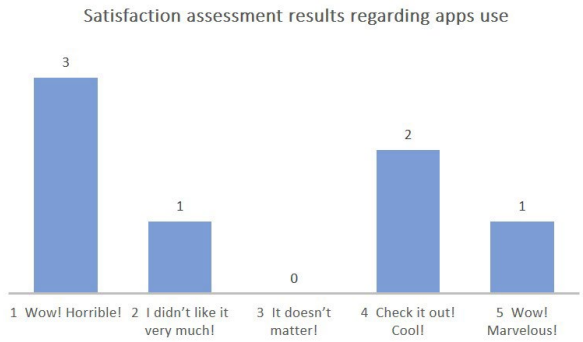


Figure 4 Satisfaction assessment results regarding apps use. (Source: created by the authors).

Participants who performed the test with the e-commerce app found it difficult to put the product in the cart (they thought the option "add to cart" was very low on the page, which can lead to cancellation of the purchase for not finding it immediately) and another difficulty they reported was that the app did not have image descriptions.

As for the local supermarket app, the participants were able to carry out the tasks, but they reported that there should be more accessibility because the images have no description and it is tiring to find a product because when you click on the departments to see the discounts, there is a lot of information before the essentials such as what the product is and how much it costs. Instead, the order on the screen reader is: (1) dates and deadlines of when the products will be discounted (this information appears before each product, making it repetitive); (2) limit on how many products can be discounted; (3) price; (4) name of the discounted product; (5) the option "I want" to place the product in the discount list.

Of the 7 (seven) participants, 4 (four) rated satisfaction as "Wow! Horrible!" or "They didn't like it very much". They reported that the apps were not accessible to people with visual impairment as they found it difficult to identify elements in the interface, which could prevent the user from proceeding with tasks. Filho and Santos (2015) state that sometimes this happens because websites and apps do not follow accessibility standards about making digital products intelligible to the person reading the screen (FILHO; SANTOS, 2015).

These results allow us to reflect with Cambiagui (2012) who highlighted that the right to eradicate architectural barriers, providing communication, physical access, appropriate programs, equipment, content, and presentation of information in optional formats should be a reality in the lives of people with visual impairments. It also corroborates with a discussion by two authors such as Bambozzi, et al. (2010), who add that information access technologies save and streamline the time of people who need a service. To verify how people with a disability are still unable to fully use the resources made available to facilitate their daily lives one understands the need to continue the debate regarding the series of problems that visually impaired people experience in a society whose services have become increasingly automated, allowing for comfort and autonomy in carrying out tasks.

While the volunteers performed the tasks on the apps, it was observed that most of them faced difficulties such as taking a long time to complete the process. This was due to the issues previously reported. So, the emotions that the participants reported when using the applications are really compatible with the observations made by the researcher, showing that they were sincere in their answers and that they understood the 3D tool.

4.3 Binaural Hearing Scale Tool (3D audio) analysis

The results regarding the tool use analysis in study are shown in Figure 5.

The results indicate that the tool was evaluated positively for most of the issues mentioned. it is noteworthy that in relation to the number of tool alternatives, it was decided to use 5 options of emotions based on the same number of SUS Likert Scale options in order to make the tool agile. As a result, most participants considered the amount sufficient. Only one person felt that the tool needed more options and another person that it should have fewer options. It is concluded, based on participant responses, that the experience with the 3D tool was satisfactory because the overall impression was quite positive. All participants liked the tool and pointed out that it is easy to use and understand.

We note that there was interest in using the audit tool, regarding this, Baumgartner et. al., (2019) explains that several studies recommend the use of questionnaires that go beyond verbal language, to increase people's interest and motivation for participating in these tests.

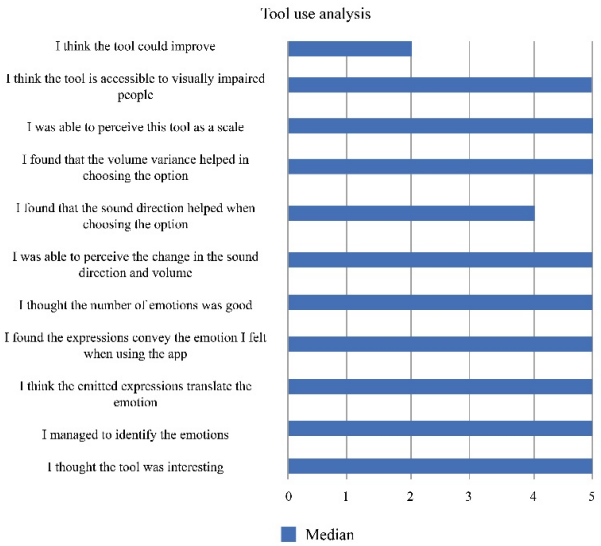


Figure 5 Questionnaire results from the 3D hearing aid assessment. 0 - totally disagree and 5 - totally agree. (Source: created by the authors).

Participants also highlighted that using expressions and intonation made the options clearer and easier to quickly choose the equivalent alternative when performing the task. The number of alternatives was another resource that facilitated expression identification, in which the participants indicated the number of the expression they had chosen, and the researcher wrote down this option.

The ease that participants had to understand was remarkable, due to the low number of requests for audio repetitions and the response speed for the choice. Only two people asked to repeat, all the others listened only once and already made the choice of option. It was also observed that there was no confusion in the choice of alternatives.

Participants reported satisfaction when using the tool's 3D audio which enabled them to better understand the options. Two participants did not notice the variation in the sound direction and volume. And, in relation to positions of the expressions, they were organized following polar coordinate logic (negative on the left and positive on the right) (MADOLE; BEGAULT, 1995) and also the SUS sequence (I totally disagree on the left side and totally agree with the right side) (BROOKE, 2014). This ordering sought to show that the tool is a sound scale that starts from the left side (negative) to the right side (positive).

With the exception of two participants who did not notice the change in sound direction, the others identified this change with negative expressions on the left side and positive expressions on the right side. This understanding was fundamental, as it was notable that the 3D tool was understood as a sound scale.

It was considered that binaural 3D audio, as it has been and continues to be used by various areas of life (SILVA, 2018; PANEELS et. al., 2013; TANG; LI, 2014; LOPEZ; ALVES, 2019; NUNES et. al., 2011) can also be used to understand the satisfaction of people with visual impairment in usability tests - even extended to other groups - allowing their impressions of satisfaction or dissatisfaction in the use of smartphones - or other systems/products – are known and served by product developers.

4.4 Tool validation through the Cronbach Alpha coefficient

The 3D tool was validated based on the result of the Cronbach's Alpha test. The calculation was obtained from the formula α=qt. items/ (qt. items-1) *[1- (add the var of the items/var of adding the subjects' points), as shown in Figure 6.

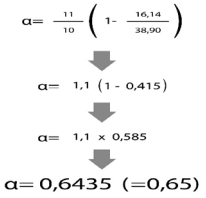


Figure 6 Cronbach's Alpha calculation which validates 3D Tool. (Source: created by the authors).

Therefore, as a result, the calculation showed α=0,65, which determines Acceptable according to Maroco and Garcia-Marques (2006) and Substantial according to Landis and Koch (1977) in other words, the 3D tool is considered consistent.

As a result of the validation, interaction with the 3D hearing aid was deemed satisfactory. And its consistency and acceptable reliability, too according to Maroco and Garcia-Marques (2006). However, it is recommended to increase the number of tests with visually impaired people in order improve this tool so that it will be used better when applying tests on users.

5. DISCUSSIONS

According to the Person with Disabilities Law (BRASIL, 2015), established in 2015 in Brazil, every person with a disability has the right to equal opportunities and should not suffer any kind of discrimination. According to the aforementioned document, the following are considered discrimination: any form of discrimination, restriction or exclusion, by action or omission, with the purpose or effect of impairing, preventing or nullifying the recognition or exercise of the rights and basic freedom of the person with disability, including the refusal of reasonable adaptations and disclosure of assistive technologies. In addition, accessibility on websites provided by companies located or with commercial representation in the country, or by government bodies, to be used by a person with disability is mandatory, providing access to the available information, according to best practices and international accessibility guidelines.

Note that with the technological advance, the daily life of people with disabilities has been facilitated and the use of the most diverse technologies has been observed. As verified in the present survey, the participants reported a frequent use of smartphones for various purposes. According to Bonilla et al. (2018), this is possible as a result of the numerous innovations with the advent of the computer and the internet. There are keyboards with magnifications and contrast, software for adjusting colors and information size (magnifying glass effect), screen reader software, speech recognition software, printed text reader software, software for augmented creation, among others. In the case of cell phones, most devices already provide resources such as screen readers integrated to the system, which give blind or low vision people access to all device features and a range of integrated applications.

Despite this, as verified in this study, many barriers are still observed in the interaction between the visually impaired person and mobile applications. These findings were also

verified by Hino et al (2021) when emphasizing that there are many problems related to the accessibility tools that are embedded in their operating system as well as their applications, that, in most cases, are not developed for people with limited vision.

It is debatable that part of the problem stems from that accessibility evaluations do not necessarily include users participation. There are programs and recommendations to assess accessibility based on the W3C/WA (Web Accessibility Initiative). According to Chalegre and Silveira (2011), in practice, these programs detect the programing code of the interface and analyze its content according to a set of stablished rules, according to the set of rules and rules. However, one of the problems with these programs is that they only evaluate if the syntax complies with the guidelines. With this, the issues detected are limited to the description of tags and do not consider usability aspects and users requirements, their perceptions or emotions while using the products.

It points out that the study and solution proposal for these problems require not only requirements conformity, but requests user active involvement in the design or research processes and this is, according to Padovani e Schlemmer (2021) an attitude advocated by the most used and recent approaches for product and interface design, such as Human-Centered Design (DCH), Participatory Design (DP) and, more recently, Design Thinking (DT).

In this sense, making research instruments accessible is a requirement to be discussed and expanded in the practice of academic and market research. Make forms and instruments accessible allow people with visual impairment to contribute with their perceptions about the world and its objects. Silva et al. (2019), contributed with an important analysis of screen readers for forms, through google, which allowed for people with visual impairment to participate in an adequate and autonomous way of remote searches.

In the present study, it was found that participants reported satisfaction when using the 3D audio tool that allowed them to better understand the options. This scale can be used combined with different research instruments in usability tests and interaction trials, involving participants with and without visual impairments and contemplating users' observations, perceptions and needs.

6. CONCLUSION

It has been observed that there are several tools used to measure satisfaction and emotions when conducting usability tests with users. In the case of the satisfaction metric, there are verbal and non-verbal tools such as protocols and cards with images and the SUS protocol, for example (BROOKE, 1996; DESMET, 2004).

However, when the user audience is directed at people with visual impairment, the available alternatives become scarce. Despite the relevant number of people with visual impairments in Brazil, there is a shortage of tools developed to collect data on the emotions felt during usability tests of digital interfaces.

Thus, the role of this work was to evaluate the validity of the 3D Hearing Tool through Cronbach's Alpha. A data collection tool regarding satisfaction has been developed to increase the participation of people with visual impairment in usability tests, allowing them to identify and give their opinion about their emotions while interacting with this device, pointing out satisfaction or dissatisfaction during the interaction. The research validated the 3D hearing tool through Cronbach's Alpha and the results showed that the tool was considered acceptable. It can be safely used by researchers and developers.

We point out as differential research the use of 3D audio technology that allows immersion in reality, providing the sensation of space and distances present in visual scales. It is believed that this tool can be used in several fields of usability, not only in the evaluation of interfaces but also in other products or systems.

As developments, it is recommended to increase the number of tests with people with and without visual impairments to improve the tool so that it is better used in the application of tests with users. It is also proposed the development of an extension of the 3D Hearing Tool model for the visual and tactile format so that it can cover the hearing-impaired public since the purpose is to make the evaluation instrument more inclusive and also enable the tool can be used in a more dynamic, agile and autonomous way by participants with disabilities.

With that, one tool is available for interface developers and usability assessments. In this way, researchers, developers, and other professionals committed to the development of accessible digital environments and interfaces will be able, with this tool, to include people with visual impairment in usability tests of their products, systems, or interfaces, identifying access barriers and measuring users' perception effectively.

ACKNOWLEDGEMENTS

This study was developed with the support of the CAPES - Coordination for the Improvement of Level Personnel Superior – CAPES (Brazil) and Federal University of Maranhão.

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