A Usability Study on the Perception of Elderly Users Interacting with CAPTCHAs

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ABSTRACT

Technologies have advanced quickly over the years, making them increasingly diverse every day. Along with this technological advancement, the number of elderly people have grown exponentially in recent years and tend to increase even more. This part of the population is having a greater interest in using these new technologies due to the ease generated. For this reason, they must be accessible to users of all ages. This research aims to evaluate the perception when using the CAPTCHA security mechanism on websites, focusing on elderly users. The main results of the study were the preference for image CAPTCHAs, considering them easier than textual ones. It was found that, in addition to age, factors such as vision problems, education and average daily Internet use influenced the resolution of CAPTCHAs. In addition, the volunteers were observed to feel at ease when resolving this security mechanism.

KEYWORDS

Usability, Older Users, CAPTCHA

1 INTRODUCTION

According to a survey by the World Health Organization [1], the world's elderly population, that is, over sixty years old, will be two billion by 2050, which will represent one fifth of the world population. By 2060, the Brazilian population aged over 65 is expected to account for 25% of the total population [2]. These very elderly group is also on the Internet – 63.5% of the elderly population in Brazil owns a mobile phone, of which 31.1% use the Internet [3] – interacting with all the facilities this medium can offer. This group may not use the technology mainly because of the impairment of their cognitive functions [4], impoverishment in the mechanisms of perception, reasoning, memory [5] [6], praxis, language, attention [7] and learning [8] and the device design [9]. Obviously, Internet use generates different feelings, reactions, and perceptions for each user, regardless of their age. Yet, in general, if the product is difficult to understand, unpleasant sensations will be generated in users, making them feel unmotivated in relation to its use and their capacity for use will be compromised [10]. Still, specifically for people who did not grow up with this technology, interaction becomes more difficult.

To better include this group in the technological context, it is important to direct efforts to meet its needs. It is supposed that computer systems usability should try to solve this kind of difficulties – if a software has good functionality, but poor usability, its users will reject it [11]. For Betiol [12], usability can be defined by the extent to which it is easy for users to interact with a specific interface and, to assess the usability, some components can be used, as suggested by Nielsen [13].

To carry out this research, which has the elderly as its target audience, one common mechanism in the current digital world was analyzed: the Completely Automated Public Turing Test to Tell Computers and Human Apart (CAPTCHA) security mechanism. The CAPTCHA mechanism is used to identify users, differentiating them from a malicious program [14]. These security mechanisms are increasingly used on various websites to prevent unwanted or malicious bots.

Based on the above, this work aims to investigate the perception in the use of the CAPTCHA security mechanism on websites, focusing on elderly users. In addition to this group, two other age groups of users were used for comparison. The inclusion of the two other groups is justified since it is only possible to compare the performance of users of different ages if other groups are also studied with the same research parameters. The groups were divided as follows, based on the study by de Lara et al. [15]: young adults (18-39 years), adults (40-59 years) and elderly (60 years or older). For this, several tasks were proposed for users to perform. For executing the tasks, a software was developed, in the WebStorm platform and using the Angular 8 language, called Captcha.

2 BACKGROUND

The origin of CAPTCHAs is linked to the increased use of the Internet. This occurrence was due to the proportion that the Internet took on at in the late 1990s, when intense investment in Information and Communication Technologies (ICT) regarding online businesses acquired growing importance [16].

The term CAPTCHA was coined in 2000 by Luis Von Ahn, Manuel Blum, Nicholas Hopper, and John Langford of Carnegie Mellon University. Moradi and Keyvanpour [17] describe the CAPTCHA as a security preservation mechanism that has already existed for a few decades and is still applicable. This security mechanism is based on the human being's ability to interpret, using challenges to differentiate a machine from man. A human being can solve CAPTCHA challenges, but a machine needs a

very high cost to solve them [18]. In practice, CAPTCHAs are Turing tests based on Artificial Intelligence (AI) and use computerized challenges that need to be discovered to gain access or continuity to the site being used [19].

The challenge is to discover sounds, images or characters that are distorted or that have a degree of similarity [19]. Images, for example, are distorted so that only humans can determine what is in their contents. Thus, it prevents malicious programs from intensively and repetitively using online services [20]. To ensure that computers do not identify the contents used in a CAPTCHA, several types of this mechanism have been developed: image recognition, text recognition, identification object, audio recognition and puzzle resolution [21]. Three methods stand out because they are easier for humans and have significant difficulty for the machine: image recognition, text recognition and audio recognition [22].

In the image recognition method, images of various objects are used to be identified [23]. CAPTCHA takes advantage of the computer's weakness in deciphering images and uses this as a security mechanism. In general, the user is expected to be able to perform an identification and recognition task of an object or image and group it into groups [17]. In the text recognition method, characters are scrambled and distorted so that the user must type them, making it one of the most difficult methods for people with disabilities and the elderly [23]. Text recognition stands out for being the cheapest method, as a computer can generate numerous questions in a short period of time [21]. When a user does not understand or is not satisfied, it is possible to repeat the process to generate a new CAPTCHA just by pressing the key responsible for the change [24]. In the audio recognition method, a noisy audio is played to be identified by the user [23]. A new feature for the user is the link to speech, in which the CAPTCHA system asks the user to repeat the phrase heard. Then, the system will process it to check if the given phrase is the same as the one the user repeated [17]. An important detail in this method to be highlighted is the difficulty in understanding when other languages are used.

According to Yan and Ahmad [25], four usability principles need to be followed: accuracy, response time, perceived difficulty, and satisfaction in performing the task. Accuracy concerns how many chances the user will need to hit the challenge. Response time is the time involved from the start to the completion of the challenge. The perceived difficulty is how difficult it was for the user to perform what was proposed and satisfaction in performing the task is the feeling of the task conclusion and whether the user would use this method again. These usability principles provide the chance to improve the system and offer the opportunity for any user, even with a disability, to be able to use it [26].

Milo et al. [27] highlighted that many internal and external factors also influence usability in CAPTCHAs, which can lead to user disappointment. As human beings are sensitive to changes, as soon as this security mechanism was introduced on the Internet, many doubts raised about its use, as well as questions about its effectiveness. As the CAPTCHA is used to access or exchange chat rooms (chats), monetary transactions and registrations on e-mail sites, greater caution is needed when a user is faced with a hard-to-understand CAPTCHA. In many cases, as the response time increases, the user gives up using this system.

2.1 The elderly and technology

For a person to be considered elderly, according to the IBGE classification, they must be over 65 years old; however, to carry out this study, the classification adopted by the Statute of the Elderly of Brazil will be used, which considers an elderly person to be one who is over 60 years old (Law n. 10741 of 10/01/2003).

Elderly people are living longer, and this population has gradually increased over the years. This demographic change has motivated researchers from different areas to find ways to improve the quality of life of the elderly, smoothing the effects of aging through medications and assistive technologies [28]. A study by Mamolo and Scherbov [29], focused on population projection in European countries, reports that there will be an expansion of the elderly population, while the rest of the population will tend to decrease. Also in this projection, it is predicted that by the year 2030, one person among four will be over 60 years old. A similar projection was made by IBGE [3] recently, predicting that the elderly will reach a quarter of the total population in Brazil in 2060.

The growth of the elderly population emphasizes the need to develop innovative approaches to help them use new technologies, transforming people in this age group into potential users [30]. Elderly people are less likely to use technological devices than younger people [31] and, for this reason, they cannot be expected to know some conventions adopted for interfaces [32], in addition to interacting differently with technology for various reasons. Your cognition is also affected, because, in aging, there is a deceleration of cognitive processes, memory capacity, less attention control, decreased vision and hearing, which contributes to greater difficulty in handling mobile devices, in addition to resulting in mistakes made when interacting with technology [33].

When designing technologies aimed at the elderly, it is important to consider the perceptual, cognitive, and motor systems of these users [34]. Furthermore, when interaction with technology is intense throughout life, learning becomes easier. Conversely, when technology is introduced later in a person's life, its use and control will be less associated with existing representations formed during neural maturation [35].

2.2 Related researches

Regarding CAPTCHAs, Novaes Neto [26] identified that the use of CAPTCHAs in chats had an insignificant influence on their adoption. Users tend to use and access more websites when they do not have CAPTCHAs, as their access becomes simpler. Therefore, although the use of CAPTCHAs as a security device makes the Internet safer and free from unwanted messages, their use can hinder and reduce user access. For Santa-Rosa e Liberato [36], despite providing a greater degree of security for users,

usability is affected, discouraging users with difficulties and disabilities. In many cases, even making mistakes several times, users tend to ignore the refresh button, which makes it possible to switch from a difficult test to an easier one.

Lee and Hsu [21] investigated the effects of age and types of distortion in textual CAPTCHAs. The survey showed that the two age groups assessed differed significantly in terms of response time and error rate. Furthermore, it was found that the type of distortion also influenced these variables. Belk et al. [22] investigated the effect of users' cognitive styles and cognitive processing skills on task preference and performance of CAPTCHA challenges. The authors argue that specific cognitive factors have a high impact on user preference and task efficiency and effectiveness. The research results support the need for versatility in the design and development of dynamic mechanisms for CAPTCHAs.

3 METHOD

The research included one case study, detailed in the following subsections. Let us emphasize that this research followed the ethical precepts determined by Resolution nº 510 [37], of April 7, 2016, and that, when volunteers were invited to participate in the research, they received an explanatory text about the objective of the research and the confidential character of the information collected. At the end of the explanation, those who agreed to participate in the research signed an Informed Consent Form. Volunteer participants were randomly selected and divided into three groups: young adults, old adults, and the elderly.

The case study was carried out in three cities in the South of the State of Minas Gerais and was applied to a nursing home, health centers, a social center, students' dwelling places, a university, and door to door.

The study was conducted by performing two similar tasks, covering three levels of difficulty in each (see Figures 1 and 2 as example), involving the resolution of textual and image CAPTCHAs. The easy level of difficulty had little visual interference, with legible letters and interspersed and well-differentiated numbers, or few illustration options to be chosen, with very distinct and sharp images. The medium level presented some interferences and fluctuations in the characters or more options and distractions in the images. Finally, in hard-level CAPTCHAs, interference, wobble, and character skew made resolution more complicated. The human perception about the inclusion or not of an image determines the difficulty in its execution.

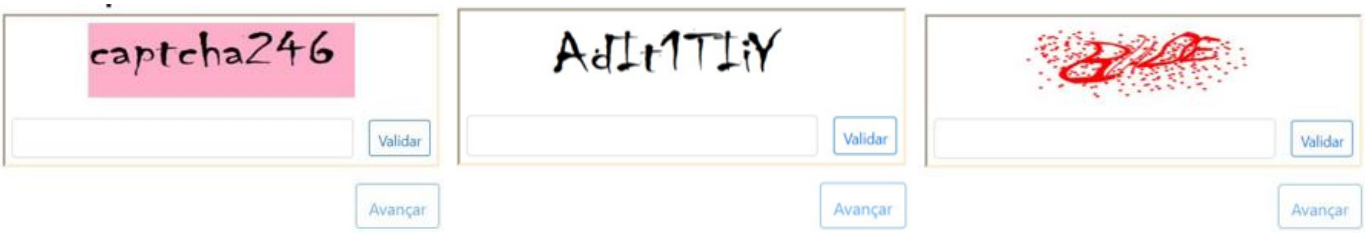

Figure 1: Examples of textual CAPTCHAs used in the research: easy, medium, and hard complexity. Source: The authors

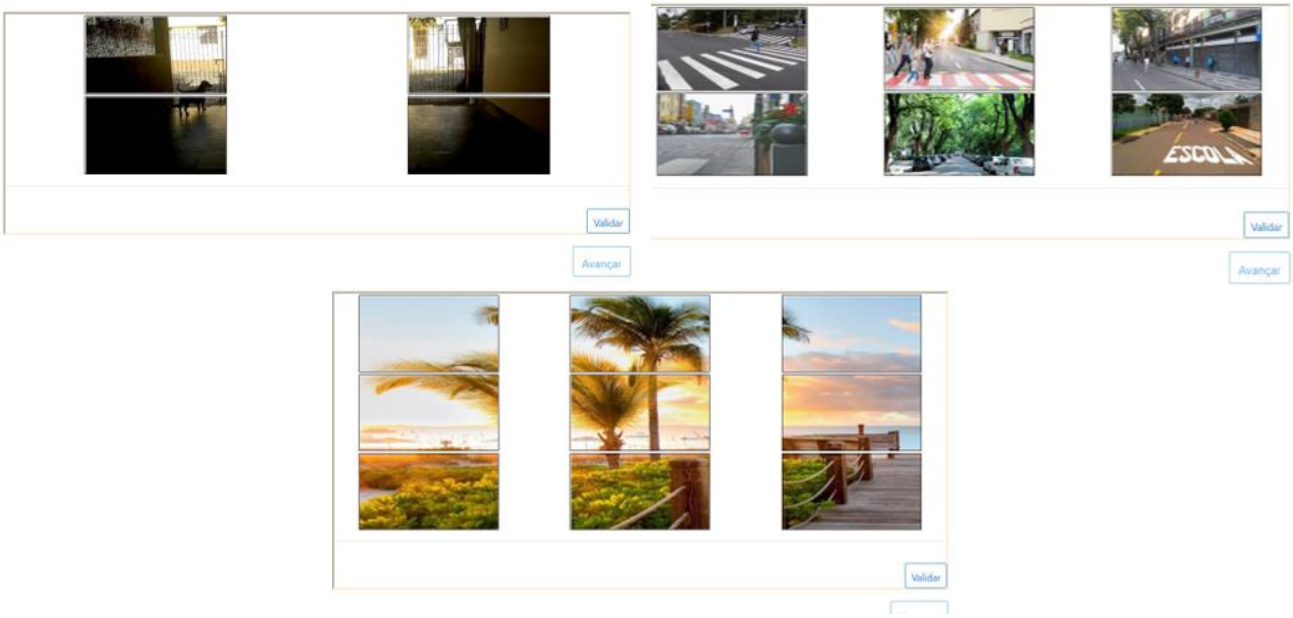

Figure 2: Examples of image CAPTCHAs used in the research: easy, medium, and hard complexity. Source: The authors

During the survey, participants respond to a questionnaire to obtain information about their profiles. At the end of the questionnaire, the volunteer was asked to agree (or not) to participate and provide their data anonymously. In addition, each volunteer was informed that they could give up the task at any time if they did not feel comfortable, in which case the task would be canceled at the same time.

The number of errors made by participants during tasks execution and the time they took to solve each type of CAPTCHA, considering the three difficulty levels, were automatically accounted by the software developed for this study. Participants were able to request assistance in using the software on each occasion, since the research was based only on their perception in the resolution of the CAPTCHAs. After completing the tasks, the volunteers received two questionnaires referring to textual and image CAPTCHAs, to express their opinions about the experience. The questionnaires were designed using a five-point Likert scale.

3.1 Criteria

The criteria used in the study were **execution**, **understanding**, **simplicity to perform the tasks**, **preference for the type of CAPTCHA** and **subjective satisfaction**. These criteria were analyzed using the four usability principles that Yan and Ahmad [25] pointed out to be necessary: precision, response time, perceived difficulty, and satisfaction in performing the task. To assess the first two criteria – execution and understanding – the answers of the first three questions of the questionnaires were analyzed. These questions refer to the user's ease of performing the task, understanding what was requested and understanding the arrangement of information on the notebook screen. This information was related to the principle of accuracy and response time. In turn, the third criterion – simplicity to perform the tasks – was analyzed based on the answers to question 4 ("How do you assess the simplicity to perform the task?"). This criterion was analyzed along with the perceived difficulty principle. The answers to question 5 provided indications of which CAPTCHA the volunteers prefer or consider easier. Finally, subjective satisfaction was analyzed from question 6 ("Would you be able to perform the same task again, if a CAPTCHA appears when using the Internet?"), showing success when the volunteer indicated that he was able to repeat the same assignment. The preference and satisfaction of volunteers were analyzed along with the principle of satisfaction. Table 1 shows the usability criteria used in this case study.

3.2 Participant profile

This study involved 120 people, 47 men and 73 women, distributed as follows: 40 young adults – 24 men and 16 women; 40 older adults – 13 men and 27 women; and 40 elderly people – 10 men and 30 women. When asked about the possibility of already knowing the CAPTCHA security mechanism, 69 participants claimed to have knowledge, and among these, 40 participants were young adults, 21 old adults and eight elderlies. For participants who had never seen or did not remember having seen a CAPTCHA at the time of the survey (39%), a brief explanation about the functioning of the security mechanism was necessary. After this simplified explanation, they were able to perform the tests. It should be mentioned that, during the application of the activities to the volunteers, three elderly people requested to skip the textual CAPTCHAs, which they considered difficult, due to the difficulty in seeing the characters. These data were counted in the survey, because when faced with this security mechanism on the Internet, there is the option to skip when it is not possible to identify the characters.

Criteria	Nº	Questions
Execution and understanding	1	How easy was it to accomplish the task?
	2	Did you manage to understand what was happening during the execution of the task?
	3	Is the information displayed on the screen easily understood?
Simplicity to perform the tasks	4	How do you assess the simplicity to perform the task?
Preference	5	Do you find image CAPTCHA easier than text CAPTCHA?
Subjective satisfaction	6	Would you be able to perform the same task again, if a CAPTCHA appears when using the Internet?
	7	Did you feel comfortable solving CAPTCHAs?

Table 1: Criteria and their questions. Source: The authors

Regarding the average daily use of the Internet, among young adults, men stated that they invested, on average, 11 hours, and 08 minutes; women spend seven hours and 14 minutes. In the group of older adults, the average time invested was four hours for men and three hours for women. This difference in average can be justified when analyzing how long users have been using the internet. In this case, men have accessed it longer than women, who started less than six months ago. For the elderly, the average time was even shorter, being two hours and 54 minutes for men and one hour and four minutes for women. When asked about the fact that they had already done some type of registration on a website, all young adults said they had. This number corresponded to half for the group of older adults (20), and, in the case of the elderly, it was even smaller, corresponding to four participants.

Elderly participants turned out to be a diverse group. Among the 40 volunteers, only one had a postgraduate degree, five had completed higher education, eight had completed high school, six had completed elementary school, and the others (20) had not completed elementary school. Most seniors were interviewed at their homes and in a community center. Regarding the use of the

Internet, about 50% of the elderly demonstrated to be active in the digital area, as 21 respondents claimed to use social networks to communicate with their family members, and eight of these were already familiar with the CAPTCHA. Despite using the Internet, the majority do not use it daily and five participants said they did not know that they used the Internet on their cell phone, as they believed that it was necessary to have a desktop for this purpose. One of the reasons cited by the elderly who do not access the Internet and do not have cell phones was the absence of a patient person to teach them and help them use it. Only five elderly people stated that they do not have and are not willing to use the Internet, as, according to them, "it takes up a lot of time in the day".

The level of education of volunteers in the older adult group was more diverse, with one with a graduate degree, six with complete higher education and one with incomplete higher education, 11 with complete high school and three incomplete, six with complete elementary education and, the others (12), with incomplete primary education. Six participants in this group stated that they did not have access to the Internet. In addition, 52.5% of the volunteers in this group stated that they knew about the CAPTCHA mechanism, with the image CAPTCHA prevailing.

In the group of young adult participants, only one volunteer had a postgraduate degree, four participants had completed higher education, 34 were still attending an undergraduate course, and one had completed high school. The ease of solving CAPTCHAs for this group was greater than for the others, as all volunteers already knew the mechanism. Furthermore, all participants in this group stated that they have been using the Internet daily for over two years. Furthermore, all the participants in this group stated that they had been using the Internet daily for over two years.

3.3 Field research tools

For executing the tasks, a software was developed, in the WebStorm platform and using the Angular 8 language, called Captcha. During the application of the tasks, the same notebook, Acer Aspire 5 model, was used. The tests did not require an Internet connection to be carried out, as all the information was stored in the computer. The tests performed were the same for all participants, having three levels of difficulty. When the volunteer got the first test right, it automatically moved to the next level of difficulty. When missing a check, he could two more tests of the same level before being subjected to the increased difficulty.

Nine types of textual CAPTCHAs were registered in the developed software, as well as the same amount for image CAPTCHAs, being three of easy level, three of medium level and three of difficult level in each category. The tasks were limited to three types per level so that the test application time would not be long, preventing fatigue in the volunteers. CAPTCHAs were created by the authors from copyright-free images, according to the degree of complexity considered by the literature for CAPTCHAs. The errors and successes of each volunteer were counted by the software and displayed in a report, containing the volunteer's identification, the date and time the test was performed, the type of CAPTCHA, the degree of difficulty and the time spent. These data were fundamental for analyzing the volunteers' perception.

4 DISCUSSION

The analyses were conducted based on the results from carrying out the tasks with both textual and image CAPTCHAs, by the three groups, and it is possible to highlight the difference in the time taken to perform each task (Table 2).

As observed, young adults were 44% faster in solving the image CAPTCHAs than the elderly, and these last ones were able to solve the image CAPTCHAs with a speed 26% higher than the textual ones. An important point to be highlighted is that part of the research was carried out in nursing homes and in a community center. In this case, the elderly and old adults carried out the research for curiosity and to find out who could solve the tests, without worrying about errors. This competition among the participants and the ease of carrying out the research meant that they solved it in less time, especially the image CAPTCHAs, which they declared to pose less difficulty. Thus, the difference in time spent on tasks between the three groups in the image CAPTCHAs was smaller than when comparing the performance of the three groups in the resolution of the textual CAPTCHA.

	Textual CAPTCHAs		**Image CAPTCHAs**	
	Time	**Error Average**	**Time**	**Error Average**
Elderly	147	2	109	1
Older adult	137	1.3	93	0.3
Young adult	93	1	61	0.3

Table 2: Time and errors average in the tasks execution by group. Source: The authors

Regarding the errors made by the volunteers, more errors were noticed with textual CAPTCHAs than with images. This difference in the average of errors between the two types of CAPTCHAs, associated with the time spent for each, can be partly explained by vision problems acquired with age, considering that the images are sharper than the texts in textual CAPTCHAs. Many volunteers found the image CAPTCHA easier, considering it a relief after a tiring series of text CAPTCHAs. Some elders and older adult participants even stated that they saw drawings and not characters in hard textual CAPTCHAs level and asked to skip the task, as they did not know how to respond. This fact corroborates the principle of Yan and Ahmad [25] about perceived difficulty, in that it is possible to observe that people prefer image CAPTCHAs to text, as they are considered easier. It was also noticed that the usual time spent on the Internet also influences the number of errors.

The first part of the case study consisted in solving textual CAPTCHAS in three levels of difficulty and then, the activities of the three levels of image CAPTCHAs were carried out. Table 3 shows the percentages of responses obtained by the questionnaires applied after the tasks were performed. In the first item, task ease, the answers showed that most volunteers considered the textual CAPTCHA tasks between easy and neutral (85%). Many elderly and old adults compared the resolution of textual CAPTCHAs with a vision test performed by an ophthalmologist, and most considered it easy or very easy because they are already used to performing this type of test in the doctor's office. Young adults' responses, in turn, ranged from easy to difficult. Respondents claimed that they did not like such a security mechanism because of the amount of attempts it took to get the right characters shown on the screen. Regarding image CAPTCHAs, the elderly understanding its resolution with a memory game. Still, many older adults equated the resolution of CAPTCHAs with a psychotechnical test applied to renew their driver's license. It is important to highlight that no volunteer found the CAPTCHA image difficult to be solved, as the comparison with activities they already knew made them feel comfortable facing the challenge presented.

		Ease		Understanding the Mechanism		Understanding Information		Simplicity		Satisfaction	
		Text	**Image**	**Text**	**Image**	**Text**	**Image**	**Text**	**Image**	**Text**	**Image**
Elderly	**Totally Agree**	7.5	55	95	97.5	92.5	97.5	10	37.5	92.5	70
	Partially Agree	52.5	37.5	-	-	5	2.5	45	60	5	7.5
	Neutral	25	7.5	2.5	-	-	-	22.5	-	-	5
	Partially Disagree	7.5	-	2.5	2.5	-	-	15	-	-	5
	Totally Disagree	7.5	-	-	-	2.5	-	7.5	2.5	12.5	12.5
Old adults	**Totally Agree**	10	67.5	92.5	95	90	97.5	10	52.5	85	87.5
	Partially Agree	52.5	32.5	5	-	7.5	2.5	35	47.5	5	7.5
	Neutral	35	-	-	-	-	-	37.5	-	5	2.5
	Partially Disagree	2.5	-	-	-	-	-	17.5	-	-	-
	Totally Disagree	-	-	2.5	5	2.5	-	-	-	5	2.5
Young adults	**Totally Agree**	7.5	42.5	67.5	72.5	20	70	32.5	42.5	75	85
	Partially Agree	27.5	42.5	25	25	35	27.5	25	45	15	12.5
	Neutral	37.5	15	7.5	2.5	5	-	22.5	12.5	7.5	2.5
	Partially Disagree	25	-	-	-	30	2.5	17.5	-	-	-
	Totally Disagree	2.5	-	-	-	10	-	2.5	-	2.5	-

Table 3: Percentage of responses to textual and image CAPTCHA tasks by item and group. Source: The authors

Regarding how the volunteers understood the **working mechanism** of CAPTCHAs, necessary to decipher all the characters or understand the images to solve the challenge, it was noticed that there was a high understanding on the part of all groups, both for the textual and image CAPTCHAs. Once again, the comparison with other activities (vision test and memory game) helped the development of the task. These data show that, when a person manages to connect the activity, he is performing with another one he is already used to, understanding occurs faster. Note that the rates of young adults were lower, as they said they needed to have all the characters and images right, at all levels, to consider having a perfect understanding.

When evaluating **understanding the information** presented on the computer screen, the results pointed to a better perception of what was happening by the elderly and older adults than by young adults. Still, it should be noted that young adults were rigorous and sought the technical and scientific understanding behind the CAPTCHAs, including entering debates after the tests to understand their operation in more detail. The old adults and the elderly, in turn, understood the security mechanism in a superficial way, understood its purpose and that the interaction of a human being was necessary to solve the challenges. However, they performed the tasks just duplicating what they saw, without worrying about mistakes or technical details.

The item **simplicity** was the one with the greatest diversity in the answers. It was possible to notice that the elderly who considered the tasks with the CAPTCHAs simple were the same that considered the research as an opportunity to distract and test their own skills, making them able to respond more calmly and with attention to detail. For older adults, the perception was that imaging CAPTCHAs are neither difficult nor complicated. Young adults reported that the CAPTCHAs were very confusing, either to differentiate between uppercase and lowercase letters, or to identify whether the picture that contained a part of the image to be selected would be valid or not. This shows that they were thoughtful and thorough, making the resolution not so simple. In the three groups, the participants preference was mostly for the image CAPTCHA. This preference can be understood due to the difficulty in interpreting the text CAPTCHA and proved when comparing the execution times and errors in the resolution of the textual versus the image security mechanism.

Subjective satisfaction was analyzed to verify which method was the best from the point of view of all volunteers. It was noted that satisfaction with image CAPTCHAs is greater than with textual ones due to the influence of the selected images, which

were called beautiful images, and which brought a feeling of joy at the end of the research, according to the opinion of several participants. Despite this, the majority among the three groups felt satisfied interacting with both security mechanisms, despite the errors that occurred in their resolutions. These results showed that, at the end of the task, there was satisfaction in overcoming the three levels of difficulty, confirming that the CAPTCHA, whether text or image, can still be used as a security mechanism to protect systems, as its acceptability is high.

5 Final considerations

The aim of the research was to investigate perception in the interaction with textual and image CAPTCHAs. The number of errors and the time spent in performing the tasks were computed by the software developed in this study. It was noted that age influenced the perception of the resolution of CAPTCHAs. Elderly volunteers had a greater number of errors and longer resolution times than the other groups due to vision problems acquired with age and reduced cognitive abilities.

Other factors also influenced the survey results, such as education and average daily Internet use. When asked about their education, many volunteers, mostly elderly, have incomplete primary education. It was possible to observe that the same volunteers did not use the Internet as much as the others who had secondary or higher education. This fact directly influenced the mistakes made in the resolution of CAPTCHAs. The longer the volunteer uses the Internet, the greater the chances that they have already come across this security mechanism, making it easier to solve the challenge.

It was noticed that volunteers who did not know the safety mechanism made comparisons with activities they already knew and felt more comfortable performing the proposed tasks. Even without knowing a CAPTCHA, or not remembering having come across one, the volunteers were able to complete the proposed tasks due to the comparison. Some elderly volunteers asked to skip textual CAPTCHAs, as they were unable to identify letters and numbers due to vision problems or illiteracy. All these data were included, because when faced with a CAPTCHA, while using the Internet, the user has the option of skipping the challenge presented by the system.

Despite the mistakes made by the participants, the two types of CAPTCHAs used in the research, image, and text, were well accepted by all volunteers. Most volunteers said they would be able to solve a CAPTCHA again. The preference for image CAPTCHA was unanimous for all groups of volunteers, despite being able to solve both types of CAPTCHAs proving that perception is predominantly visual, as shown by Teixeira [38]. This preference can be proven by the time spent in performing the task, since, in all the groups, the time to solve an image CAPTCHA was less than that to solve a text CAPTCHA.

It was concluded that several factors influence the perception of human interaction with a CAPTCHA, but age is the strongest influencing factor due to the limitations caused by age. However, it is possible to make a CAPTCHA more accessible to users when using only the image CAPTCHA, as there are no obstacles for visually impaired or illiterate people. Images are sharper and easier to be perceived, in addition to being easier to select.

Indeed, the performance of the groups is not expected to be different (as in other studies published in the literature). On the contrary, in this research, we reinforce the need to emphasize how the elderly group falls short of usability and are therefore excluded from several universes that require the use of technology. Hence, usability must provide conditions for this group to be properly integrated into society. We also believe that, in the age of its popularity and variety, surveys of this nature are important because using the wrong captcha, for example, can isolate older users with less digital awareness of the data.

Finally, it is important to point out that this research does not end with this study. Undoubtedly, several developments can be explored. For example, it is important to further the research covering statistical tests, including hypothesis tests in future work. Also, it is relevant to involve elderly users to evaluate the usability of some other virtual assistants available in the market, such as Xiao Ai (Xiaomi), Cortana (Microsoft) and Alexa (Amazon). Another possibility could involve comparing task execution with elderly participants, with and without the use of virtual assistants. Furthermore, it is interesting to continue the research to assess the perception and performance of elderly people in the use of other types of existing challenges, such as video CAPTCHAs, the usability of this type of CAPTCHA and the cognitive and emotional reactions in their use. Another possibility for future research would be the automation of CAPTCHAs explored during the research, using existing libraries, thus increasing variations during the tests for the types of CAPTCHAs presented.

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