CAPTCHA and Accessibility
Is This the Best We Can Do?

Lourdes Moreno, María González and Paloma Martínez
Computer science department, Universidad Carlos III de Madrid, Av. Universidad, 30, Leganes, Spain

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Abstract: Web access is affected by a great amount of accessibility issues that do not allow some users to access all information presented. Therefore, Web accessibility is an important issue because everybody should access Web content independently of their access features. Among these accessibility issues, a Web content element that interferes with Web accessibility is a CAPTCHA. A CAPTCHA is a challenge-response test used to determine whether or not the user is a human instead of a computer or a robot. This type of element causes accessibility barriers especially to users with disabilities. This paper presents an overview about Web accessibility and CAPTCHA. Besides, an analysis of the accessibility barriers and a solution proposal depending on the type of disability is provided. Moreover, a survey of CAPTCHA approaches is introduced and its results are shown. With the knowledge gathered, a data discussion is provided. The lesson learned is that the CAPTCHA objective must be that security checks should be responsibility of websites or servers, that is, they cannot be delegated to the user.

1 INTRODUCTION

The Web sites security directive uses Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) in order to avoid input that has been generated by a computer or a bot, and authenticate that whoever is accessing is a human user. There is a trend to use this content element on many websites and sometimes it provokes accessibility barriers that avoid Web content access to people with disabilities. Besides, a lot of CAPTCHA techniques have emerged that cheat through software allowing computers or robots to access the content and that include more accessibility barriers. Users with disabilities need assistive technology to access to the Web, and CAPTCHA techniques. CAPTCHA techniques must take account it to provide a supported access to this technology. In order to deal with these accessibility barriers, most users have to be helped by other people. This fact has caused that some people protest against it as in the case of Australia (Hawkins, 2013) to ask for the elimination of Web CAPTCHA and the use of other ways of security such as SMS or mails. On the other hand, it is also important to highlight that security should be included by the server avoiding that users have to be concerned about it.

The motivation of this paper is to carry out a study concerning accessible CAPTCHA taking into account the access features of the users with disabilities. After analysing all this information, accessibility barriers to perceive, to solve, to access (answer -typing, to pointing, ..- and submit) of the CAPCHA for several user profiles of people with disabilities have been distinguished and proposed solutions are provide in each user profile.

The remainder of the paper is organised as follows: Section 2 covers the background of accessibility and some CAPTCHA issues. Section 4 introducs an analysis of accessibility barriers and a solution proposal. In section 5, a survey of several CAPTCHA approaches are shown. Finally, discussion of the data and lessons learned are presented in Section 7.

2 BACKGROUND

A large increase of CAPTCHA on the Web is observed. The growth of CAPTCHA is due to it is a security mechanism which can be introduced easily.. But it has not been properly carried. The accessibility has not been in mind when this element

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has been integrated on the Web.

2.1 Web accessibility & CAPTCHA

It is essential to achieve an accessible Web in order to provide equal access and equal opportunity to people with diverse abilities. Therefore, an accessible CAPTCHA should be a mechanism that avoids the access of robots but not the access of a human user independently of his language, knowledge or whether the user has any kind of disability that hinders his interaction with Web content.

Currently, the use of CAPTCHA causes a great number of accessibility barriers. In order to avoid these barriers, designers have to know what the main standards and regulations have to follow in order to design an accessible CAPTCHA. Every website has to be designed according to accessibility standards that allow users to access Web content independently whether or not they have a disability.

Regarding accessibility standards is important to highlight the World Wide Web Consortium (W3C) with its Web Accessibility Initiative (WAI) (W3C, 2012). WAI includes various works such as User Agent Accessibility Guidelines (UAAG), Authoring Tool Accessibility Guidelines (ATAG) and the most important standard, the Web Content Accessibility Guidelines (WCAG) (W3C, 2008),

WCAG 2.0 is the set of accessibility guidelines most referenced in the world and since 2012 is a standard ISO/IEC 40500:2012, Information technology - W3C Web Content Accessibility Guidelines (WCAG) 2.0). Following this standard, there are several initiatives in different countries related to Web accessibility such as: Section 508, BITV 2.0, RGAA, AODA among others. These initiatives are similar to WCAG 2.0, being in some case a copy of it.

Following the WCAG 2.0, the Success Criterion 1.1.1 indicates that *Non-text content explicitly excludes the requirement to supply a text alternative to a CAPTCHA image for this very reason. But that doesn't let the developer off the hook, because it required that: ...text alternatives that identify and describe the purpose of the non-text content are provided, and alternative forms of CAPTCHA using output modes for different types of sensory perception are provided to accommodate different disabilities* (W3C, 2008).

The difficulty in making a CAPTCHA image accessible is that providing a text alternative of the image, as required for screen reader users to understand the content, also supplies the answer to the bot. Besides, designers should take into account some techniques such as:

- Technique G143 (*Providing a alternative text that describes the purpose of the CAPTCHA*): the purpose of the technique is to provide information via the alternative text that identifies the non-text content as a CAPTCHA.
- Technique G144 (*Ensuring that the Web Page contains another CAPTCHA serving the same purpose using a different modality*): the purpose of the technique is to reduce occasions in which a user with a disability cannot complete a CAPTCHA task.

Others international standards found related to accessibility are: the ISO 9241-151, *Ergonomics of human-system interaction - Guidance on World Wide Web user interface*, the ISO 9241-171, *Ergonomics of human-system interaction - Guidance on software accessibility* that provide guidance on software accessibility and the ISO/IEC TR 29138-1, *Information technology - Accessibility considerations for people with disabilities - User needs summary*.

2.2 Disabilities

A great amount of web applications and websites present accessibility problems and they are not adapted to people taking into account their type of disability. The main types of disabilities are: Visual disability (blindness, low vision and color-blindness), Auditory disability (deaf and hearing loss), Motor disability (muscular dystrophy, multiple sclerosis, etc.) and Cognitive disability (WebAIM, 1999).

Besides this type of disability, it is important to take into consideration the degrees of a disability. For example, there are four degrees of hearing loss, mild, moderate, severe and profound.

On the other hand, a user can have more than one disability or multiple disabilities. For example, many people develop age-related impairments. These combinations of disabilities cause users have to face more accessibility barriers.

People with disabilities sometimes use other technology (software and hardware), called Assistive Technology (AT), to interact with the Web. There are types of AT that allow users to access web content. For example, for visual disability, screen readers, adapted keyboard, screen magnifiers and braille embossers can be highlighted.

The review carried out in this paper may be helpful to designers so that they can keep in mind several aspects regarding type of disabilities that

have to be taken into account when they are accomplished the design, such as: the variety of types and degrees of disabilities and the technology that can help them to allow users to access Web content.

2.3 CAPTCHA

The aim of CAPTCHA is to avoid robots and computers can register in a forum, create an email account or access to a public service. This element is also used as security mechanism when a user introduces three times a wrong password trying to access a website. On the other hand, Google uses a CAPTCHA called reCAPTCHA (Google, 2013) in order to improve book digitalization and stop spam at the same time.

The most common form of CAPTCHA is illustrated below, where distorted alphanumeric characters are presented as an image. The user is expected to type the characters they see into a form field (see Figure 1). The assumption is that most bots are not capable of recognising or interpreting the distorted alphanumeric characters and will fail the CAPTCHA.

Figure 1: Example of the most common CAPTCHA.

3 RELATED WORK

According to (W3C, 2005), there are six possible solutions using CAPTCHA or other alternative techniques, although these solutions do not solve completely the problem of the accessibility:

- Logic puzzles: uses simple mathematical word puzzles, trivia, etc. Among problems, it can be highlighted the problems that appear when users have cognitive disabilities. Other problem is that systems have to maintain a great number of questions.
- Sound output: offers a non-textual method of using the same content. The problem is that sometimes the audio can be unintelligible because of background noise and also the language can be a barrier because of different pronunciation.
- Limited-use accounts: creates limits for new users can mean of making sites unattractive targets to robots. Having to take a trial-and-error approach to determine a useful technique is a downside.
- Non-interactive checks: non-interactive mechanism can be used instead of CAPTCHA or interactive approaches. Spam filtering and heuristic checks are two non-interactive approaches.
- Federate identity systems: tries to set an identity of each client and maintain it across all sites that use the same service. This solution presents three approaches: single sign-on, public-key infrastructure solutions and biometrics.
- Other approaches: one approach is the use of artefacts of identity such as credit cards or national ID. Other approach uses SMS or email to verify the identity. The problem of using SMS is that users need a mobile phone and the use of mobile phones can cause problems for users with disabilities.

In (Holman et al., 2007), a proposal and a development of a new form of CAPTCHA that combines visual and audio information to facilitate the access of users with visual impairments is presented. Other work shows a study in which 150 on-line forums are analysed to know if they use CAPTCHA and what type of CAPTCHA is used. After the study, they concluded that the most used CAPTCHA is the text-based CAPTCHA and they realised that accessibility alternatives were rarely provided (Kuzma et al., 2011). (Shirali-Shahreza and Shirali-Shahreza, 2011) evaluates how easy CAPTCHA is for humans as well as review accessibility of the different kinds of CAPTCHA especially for visual impaired and elderly people. A new audio CAPTCHA development (called SoundsRight CAPTCHA) and an evaluation of it carried out by blind users are described (Lazar et al., 2012). In (Bigham and Cavender, 2009) a study with blind users is carried out. The study demonstrated that existing audio CAPTCHA are inadequate alternatives. Due to this fact, an optimization of the interface to solve these CAPTCHAs for non-visual use by localizing the playback controls into the answer box is presented. (Markkola, and Lindqvist, 2008) in which efforts on designing accessible voice CAPTCHA for Internet Telephony are discussed. A set of current CAPTCHAs are shown in (Roshanbin and Miller, 2013), attacks against them and an investigation about its robustness and usability are presented as well as a set of ideas to develop a CAPTCHA. Analysis of "User with disability -

CAPTCHA - Interaction".

In order to make a thorough study of the barriers that people with disabilities face when interacting with CAPTCHA, an analysis using the Scenario Method has been carried out in this work (Carroll, 1994). Scenarios are useful to get used to problems and solutions that users have to face up.

Table 1 shows a summary of the defined scenarios taking into account the different kinds of disabilities, combinations between them, their access needs and the types of barriers in the interaction with the CAPTCHA (perceive, solve and access (answer and submit)). Besides, as a conclusion of the analysis of each scenario, proposed solutions based on standards and expert heuristics are presented. In this analysis has been considered the CAPTCHA most common, i.e., with distorted text which is presented as an image (see Figure 1).

In order to illustrate the scenarios, one of them, the scenario regarding visual disability is going to be explained. As far as visual disability is concerned, it is defined a scenario where a blind or low vision user needs AT (such as screen readers) to access information provided by a CAPTCHA. As a

Table 1: Scenarios defined according to types of disability.

Type of disability	*Acc. Barriers [Perceive, Solve, Access (Answer/ Submit)]*			*How to access CAPTCHA?*	*Proposed Solution*
Visual disability	X		X (*)	User may need AT such as magnifier or screen reader	Provide the user the perception of the CAPTCHA with auditory modality. In addition, the WCAG 2.0 must be achieved. So, user can access with his/her AT such as keyboard to ensure that user accesses (Answer / Submit) the form.
Auditory disability					User should not have any problem to perceive, solve and access (answer, submit) the form because it is perceived by visual modality. In addition, the WCAG 2.0 must be achieved.
Motor disability			X (*)	User accesses with keyboard or may need AT	The WCAG 2.0 must be achieved. So, user can access with his/her AT such as with keyboard to ensure that user accesses (Answer / Submit) the form.
Cognitive disability		X	X (*)	User can have difficulties to understand and solve CAPTCHA	Limiting the degree of difficulty of CAPTCHA to ensure that user solves it. In addition, the WCAG 2.0 must be achieved.
Visual and auditory disability	X		X (*)	User may need AT such as Braille Displays	The WCAG 2.0 must be achieved. So, the user can use his/her AT that allows him/her to perceive and access (answer and submit) the form.
Visual and motor disability	X		X (*)	User may need AT such as screen reader, magnifier, only keyboard and other AT	Provide the user the perception of the CAPTCHA with auditory modality. In addition, the WCAG 2.0 must be achieved. So, user can access with his/her AT to ensure that user accesses (Answer / Submit) the form.
Visual and cognitive disability	X	X	X (*)	User may need to use AT such as screen reader, magnifier and he can have difficulties to understand and solve CAPTCHA	Provide the user the perception of the CAPTCHA with auditory modality. Besides, the difficulty of how to solve the CAPTCHA should be restricted to ensure that user can solve it. In addition, the WCAG 2.0 must be achieved. So, user can access with his/her AT to ensure that he/she accesses (Answer / Submit) the form.
Auditory and motor disability			X (*)	User accesses with keyboard or may need AT	User should not have any problem to perceive and solve the CAPTCHA because it is perceived by visual modality. But, it is necessary that WCAG 2.0 is complied to ensure the access. So, user can access with his/her AT such as keyboard to ensure that user accesses (Answer / Submit) the form.
Auditory and cognitive disability		X	X (*)	User can have difficulties to understand and solve CAPTCHA	User should not have any problem to perceive and solve the CAPTCHA because it is perceived by visual modality. But, it is necessary limit the degree of difficulty of CAPTCHA to ensure that user can solve it. In addition, the WCAG 2.0 must be achieved.
Motor and cognitive disability		X	X (*)	User accesses with keyboard or may need AT and he/she can have difficulties to understand and solve CAPTCHA	The difficulty of how to solve the CAPTCHA should be restricted to ensure that user solves it. The WCAG 2.0 must be achieved. So, user can access his/her AT such as with keyboard to ensure that user accesses (Answer / Submit) the form.

(*) If web content does not fulfil the WCAG 2.0.

proposed solution, incorporating an alternative audio in the CAPTCHA is proposed, which can be accessed and controlled by keyboard following the WCAG 2.0. It is essential to highlight that in this case solving a CAPTCHA is not the problem; truly, the problem is the perception of the CAPTCHA. If a user can perceive a CAPTCHA, usually he can solve it easily; being crucial that CAPTCHA and the Web page have been developed following WCAG 2.0 and provide access through AT.

In conclusion, regarding to the perception of CAPTCHA, the most affected groups of disabilities are visual and multiple disability that include visual and motor disabilities. Although incorporating audio can solve the main barriers to accessibility.

The cognitive disability and multiple disability that include cognitive disability are the groups which have observed more barriers to solve the CAPTCHA test. Although it seems clear how to avoid barriers limiting the test difficulty, in fact it is not, because the simplicity of the test may not prevent the access of malicious web robots.

With regard to access to the CAPTCHA (typing the characters into a form field and submit the form), the disability groups most affected are motor impaired users using AT, visually impaired users to access for screen reader and multiple disability that include visual and motor disabilities. In this case, the accessibility barriers are solved when the web page and the CAPTCHA comply with WCAG 2.0 that provides support to the AT.

The consequence of this analysis is that the users with more accessibility barriers and also more difficult to provide them an accessible CAPTCHA includes people who: are blind and vision impaired and cognitive disabilities (dyslexic, with difficulty reading...).

In the case of multiple disabilities, the proposed solutions are not easy to carry out, due to the existence of a conflict between the specific solutions with the aim of providing a universal solution.

4 CAPTCHA APPROACHES IN ACCESSIBILITY SCOPE

Some CAPTCHA approaches developed with accessibility requirements have been found and analysed as follows.

4.1 Survey of Accessible CAPTCHAs

For the analysis conducted, we have assumed that the web page complies with WCAG 2.0 in order to isolate the accessibility of CAPTCHA itself and the context of use.

The approaches found are described and discussed below. Table 2 shows a summary of the analysis results obtained.

Table 2: Summary of CAPTCHA survey.

	Disabilities			
CAPTCHA Approaches	*Visual*	*Auditory*	*Motor*	*Cognitive*
1: Form test with simple question (1)	✓ (*)	✓	✓	X
2: Form test with simple (2)	✓ (*)	✓	✓	X
3: Empathy to solve	✓	✓	✓	X
4: Advertisement to solve	X	X	✓	✓
5: Recognising to an animal	X	✓	✓	X
6: Access to the video	X	✓	✓	✓
7: 3D object recognition	X	✓	✓	X
8: Composing a phrase	✓	✓	X	✓
9: Solving a Mini game	X	✓	X	X
10: Moving the sliders	✓ (*)	✓	✓ (*)	✓
11: HoneyPot (without using CAPTCHA)	✓	✓	✓	✓

(*) High interdependence with the- WCAG 2.0 Compliance- and support with keyboard and AT (screen reader).

- Approach 1: a form test which presents a simple question. This question can be read by a screen reader to help blind users and enlarged by a screen magnifier to help low vision users. As downsides, it can present problems related to cognitive disabilities and it only uses Spanish language, therefore, a foreign person cannot solve this CAPTCHA.
- Approach 2: A CAPTCHA used by Aragon Government of Spain to set an appointment with the doctor. In order to set an appointment, the user, besides setting his/her National Insurance Number and surname, has to solve a CAPTCHA. To solve it, the user has to write a word that appears in red color or underlining in a sentence. Blind users can used screen magnifiers and screen readers to perceive, solve and access the CAPTCHA, although, it can present problems with users with cognitive disabilities and color-blindness considering that they cannot distinguish the color that it uses to select the word. Other disadvantage is the CAPTCHA language.

- Approach 3 (see Figure 2): this approach is based on the empathy to solve CAPTCHA, because depending on the user answer it is assumed if the user is a human or a robot. User with cognitive disabilities can have difficulties because he/she does not know what option selects. Besides, there is a language barrier considering that it is only provided in English.

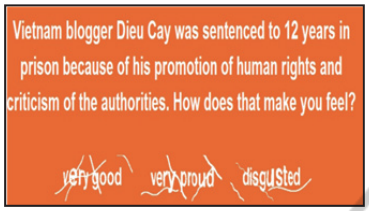

Figure 2: CAPTCHA of approach 3 (http://captcha.civilrightsdefenders.org/).

- Approach 4 (see Figure 3): this approach uses advertisement together with CAPTCHA. This fact allows website owner to earn money when CAPTCHA is correctly solved. As far as accessibility is concerned, this approach provokes accessibility barriers, for example, a user with visual disability does not solve CAPTCHA although the user is listening to the advertisement because the solution of the CAPTCHA appears in the image that is shown. Besides, a deaf user could not solve it, because sometimes the solution is a slogan that is listened in the video.

Figure 3: CAPTCHA of approach 4 (http://www.solvemedia.com/).

- Approach 5 (see Figure 4): the Animal CAPTCHA enterprise uses CAPTCHA to recognise the animals that appear in the distorted image. Users with visual disability cannot solve this type of CAPTCHA and sometimes, users with cognitive disability find problems to solve it.

Figure 4: CAPTCHA of approach 5 (http://www.teoriza.com/captcha/example.php).

- Approach 6 (see Figure 5): The CAPTCHA is a video in which characters are provided through an image and/or by auditory modality. On one hand, the audio may be intelligible. On the other hand, the user with visual disability can not access information of the distorted alphanumeric characters included into image; therefore, users with visual and auditory disability could have problems to perceive CAPTCHA.

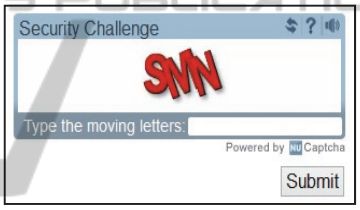

Figure 5: CAPTCHA of approach 6 (http://www.nucaptcha.com/features).

- Approach 7 (Figure 6): the solution of Yuniti is based on 3D object recognition. As aforementioned in other solutions, users with visual disability cannot access the information and users with cognitive disability have difficulties to interpret the object if it is seen from different angles.

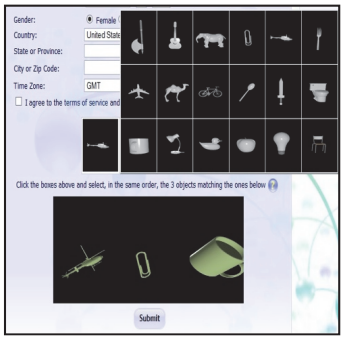

Figure 6: CAPTCHA of approach 7 (http://www.es.yuniti.com/register.php).

- Approach 8 (see Figure 7): this CAPTCHA shows a table with several columns which are composed of words. In order to solve CAPTCHA, user has to set a phrase selecting a word of each column. Among drawbacks, it can be highlighted the language of the CAPTCHA, in this case English, and problems for users with motor disabilities if words are so close complicating their selection via keyboard.

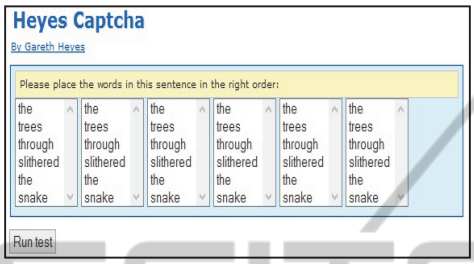

Figure 7: CAPTCHA of approach 8 (http://www.businessinfo.co.uk/labs/HeyesCaptcha3/heyes_captcha_test.php).

- Approach 9 (see Figure 8): instead of using a CAPTCHA, it is used a mini game. This CAPTCHA provokes accessibility barriers for users with visual disability, users with cognitive disability because they are not able to understand the game and users with motor disability. Although, this type of CAPTCHA provides audio, this audio can be incomprehensible. Other drawback is the language; currently it is only available in English.

Figure 8: CAPTCHA of approach 9 (http://areyouahuman.com/).

- Approach 10 (see Figure 9): it tries to move a slider from left to the right. It causes problems for blind users if the web content is not accessible by keyboard and screen reader and users with motor disabilities with dexterity problems. A blind user would need that his/her assistive technology allows user to know the position of CAPTCHA and to where move it.

Figure 9: CAPTCHA of approach 10 (http://theymakeapps.com/users/add).

Others solutions (Approach 11) which can solve the problem of CAPTCHAs are to avoid the use of them. It is considered that server should face up spam instead of user. An example is the project HoneyPot (HoneyPot, 2004). This proposal is based on that robot only interprets HTML code of web page, but they do not pay attention to CSS code, considering that, a field that user do not see could be hidden and, therefore, it could stay empty when the form is filled in. On the other hand, the robot could see the field and fill in it. In this way, a robot could be discovered. This idea avoids user to have to solve challenges that many times provoke accessibility barriers.

4.2 Discussion

The conclusion obtained is that users with cognitive disabilities are the users who have more difficulties followed by blind users. The reason of this conclusion is due to the main problem of users with cognitive disability: they do not have a good perception of the CAPTCHA. On the other hand, blind users also have problems because most CAPTCHAs are perceived through a visual canal.

Despite that the CAPTCHAs try to be accessible for people with disabilities, they do not achieve this goal completely, considering that if they provide a good solution, this solution could be easy to tackle by the robots and computers. Therefore, after the review carried out in this section, we consider the best solution is to avoid accessibility barriers by using other system to control spam instead of using CAPTCHA.

5 LEARNED LESSONS AND CONCLUSIONS

The use of CAPTCHA on the Web provokes several accessibility problems, especially for people with disabilities. This fact has motivated this work.

This paper introduces a research work which includes: a study of Web accessibility and CAPTCHA, a study of the kinds of disabilities and their accessibility barriers. According to findings of this study, the disability groups most affected by the accessibility barriers when they interact with Web content CAPTCHA are the users with cognitive and visual impairments, or multiple disability that include them. Besides, a survey and analysis of current CAPTCHA approaches in scope accessibility has been shown.

Considering that not all users can perceive, solve and access (answer y submit) the CAPTCHA, the challenge would be to design a CAPTCHA such that several alternatives to perceive the CAPTCHA and several methods to communicate the answer will be provided to the user following WCAG 2.0 techniques. In order to provide a solution proposal, as alternatives to perceive the CAPTCHA, there are two possible solutions: visual CAPTCHA and auditory CAPTCHA. But this proposal should take into account cognitive barriers.

To conclude, it is possible to design proposals CAPTCHA that can present a high level of accessibility, but unfortunately accessibility barriers continue to occur.

This lack of solutions leads us to ask ourselves whether the server has to be in charge of security without involving the final user or not. It should continue working on security solutions that prevent the use of the CAPTCHA. Some solutions already exist and can be used as using a system to control spam such as Approach 11 or email instead of using a CAPTCHA.

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