A Review of Websites and Mobile Applications for People with Autism Spectrum Disorders: Towards Shared Guidelines

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Abstract. Many studies show the effective positive impact of using computer technologies to support the lives of users with autism spectrum disorders (ASD), for simplifying interaction with other people, for organising daily activities, for improving relation with family and friends. Despite that, only a restricted part of the current websites is accessible for people with ASD. In this paper, we discuss a set of guidelines that should be followed by designers while developing websites or mobile applications for users with ASD. We review many of the existing websites and applications in order to check which comply with all, or parts of these guidelines. We finally highlight current common limitations and address new challenging research directions.

Keywords: Information and communication technology · Mobile applications · Websites · Autism spectrum disorders

1 Introduction

The wide spread of Information and Communication Technologies (ICT) and the increasing use of mobile devices, as smartphones or tablets, have changed the life of people with disabilities and in particular with Autism Spectrum Disorders (ASD), i.e., with disorders mainly related to impairments in social and communication interactions. Although users with ASD are different one from another, they generally show good abilities in using computer technologies. Thus, using them in a proper way, can become a very powerful interaction tool.

In this paper, we are interested in discussing the guidelines for developing accessible websites and mobile applications for users with ASD, and to identify typical limitations of existing tools. With this aim, in the first part of this paper, after an introduction to the autism spectrum disorder (Sect. 2), we will discuss, compare and summarise existing guidelines already present in the literature that we approve (Sect. 3). In the second part, we will analyse existing websites and mobile applications and compare them, in order to highlight which of them comply with all or parts of the guidelines (Sect. 4). We will finally discuss, which,

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in our opinion, are the future trends in the development of usable and accessible technologies for users with ASD (Sect. 5).

2 The Autism Spectrum Disorder

The Autism Spectrum Disorders is defined by the American Psychiatric Association as a neuro-developmental disorder with persistent impairments in social communication and social interaction, and restricted, repetitive patterns of behavior, interests, or activities [37].

The *incidence* of this disorder is not negligible. In [38], the authors present an interesting study on worldwide available data that estimates at the date of 2010 the number of people with ASD as 1 out of 132. The study finds no evidence of a change in prevalence for ASD between 1990 and 2010, although there are some small changes depending on regional origins. A more recent study conducted in 2012 among 346,978 children aged 8 years in 11 different cities of the United States, shows a general evidence of one child in 68 with ASD.

Each person with ASD is different, this is where the term "spectrum disorder" comes from. The areas which are most affected are: social interaction, social imagination, and social communication. Regarding *social interaction*, typically, people with ASD tend to isolate themselves showing no interest in other people, do not have a good eye contact, try to avoid physical contacts, have problems processing their own emotions and the ones of people around them. Their *social imagination* is limited: They tend to avoid symbolic games, tend to repeat the same game or even movements over and over (hand flapping, spinning or waving objects, etc.), get frustrated when something changes in their daily routine. Finally, they often show impairments in *social communication*. These impairments are often related to language delays or, in some cases, to the complete lack of verbal communication. People with ASD have also problems understanding instructions, gestures and so on. Finally, they often show *limited attention*, i.e., they are able to concentrate on tasks for a limited amount of time, and have also *Sensory Processing Disorders* (SPD), i.e., have problems processing information from the five senses, from the vestibular system, and/or the positional sense [52].

Modern therapies propose very different approaches (which are out of the scope of this paper), however, it is widely known that people with ASD usually present good visual abilities, such as visual memory, i.e., are able to represent concepts by sequence of images [46]. Thus, to support these individuals many of the proposed therapies rely on the use of photographs, images, flowcharts, cartoons, checklists, etc. What we will be concentrating on in this paper, is the use of technology to support all the therapies, and in particular, the use of images as a very powerful communication tool. In particular, to support communication interventions, often speech therapies are also sustained by Augmentative and Alternative Communication (AAC) techniques, which are based on the use of symbols or images as a method for communicating [53]. The most common AAC approach is the Picture Exchange Communication System (PECS): users communicate needs and requests by exchanging pictures with their partners; these

pictures are laminated and stored in a special book that has to be carried around [32]. Another AAC technique is, e.g., the sign language, which can be very effective, but however requires the partners to be trained, and thus restricts the communication to a limited set of individuals. An evolution of AAC techniques relies on the use of different computer devices such as tablets, smartphones, etc. These new tools allow to increase number of stored images, have limited physical size, and can thus be carried out everywhere.

3 Website and Application Accessibility Guidelines

Many studies show the effective positive impact of using computer technologies to support the lives of users with ASD, for simplifying interaction with other people, for organizing daily activities, for improving relation with family and friends [39,51]. Moreover, users with ASD show a positive attitude towards computer technologies due to the predictability of the interaction - in contrast to normal day-to-day interaction with other people - and due to the perfectability of the tool, that may induce repetitive behaviours, usually preferred by this set of users. Thus, ICTs are powerful tools for improving their learning process [49].

The set of available computer technologies is very wide, since it ranges from virtual reality, to robotics, multitouch interfaces, websites, Web apps, affective computing. These tools are often customizable with respect to the different users' abilities, and thus targeted to the different skills. We here focus only on websites and (mobile) applications.

Accessibility makes users with a wide range of abilities able to perceive, operate, interact and understand a user interface [35]. The target users might have physical (visual, auditory, etc.), cognitive or neurological disabilities, might be children or elderly people. Accessibility has always been a big concern for websites and app developers, however, it is often neglected during the development phase mainly due to the lack of knowledge by the developers, and also to the extra costs it introduces. This is in contrast with the statement declared during the 2016 United Nations Convention on the Rights of Persons with Disabilities (CRPD), that access to information technologies has to be considered a basic human right [28].

Moving towards this direction, in 2012 the W3C [29,35] has created a new task force group, called Cognitive and Learning Disabilities Accessibility Task Force (COGA), whose aim is to propose accessibility guidelines for Web accessibility for people with cognitive or neuronal disabilities [36]. The COGA group, together with the Protocols and Formats Working Group, and the Web Content Accessibility Guidelines Working Group, has published in 2016 some interesting general guidelines for the development of websites for users with Cognitive and Learning Disabilities [48]: They are too generic, and not directly targeted to users with ASD, which typically show other specific problems such as limited attention, sensory hypersensitiveness, limited text comprehension, etc. They can be a good starting point, but more specific targeted issues should be taken into account, together with further guidelines that apply to more general computer applications.

In the last years some work have been devoted to the definition of guidelines for people with cognitive disabilities [34,39,40,42,45,48,51]. However, while dealing with users with ASD with cognitive disabilities, more specific features have to be added to the general ones. Thus, starting from the international standard reference model of WCAG 1.0 and WCAG 2.0 [29], other practical and operative guidelines have been proposed [30,33,34,39,40,42,45,50,51]. Note that in general, while developing a website, or an application, it is a good idea to include an accessibility specialist in the team so to design and then evaluate the results of the design in a proper way [50].

We studied current literature, comparing the shared (and not) guidelines, and we present, in Table 1, the guidelines we approve, divided in four macro-areas: graphical layout, structure and navigation, user and language (indicated respectively by G1-G6, N1-N3, U1-U3, L1-L2).

Table 1. Accessibility guidelines for users with ASD

G1	The general design and the structure should be simple, clear and predictable, secondary content that distracts the user should be avoided
G2	The content should be predictable and should provide feedbacks
G3	Pictures should be copiously used together with redundant representation of information
G4	Pictures can be drawings, photographs, symbolic images, should be easy to understand, should not go in the background, should be in a sharp focus
G5	Background sounds, moving text, blinking images and horizontal scrolling should be avoided
G6	The text should go with pictures. It should be clear, simple, and short (at most one sentence on a line); should be in a big font (14), in plain Sans-serif style (e.g., Verdana), in a mild color. Headings and titles should be used
N1	Navigation should be consistent and similar in every page/section
N2	The website and every applications should have a simple and logical structure, the user should be able to easily navigate inside
N3	Add navigation information and navigation buttons at the top and the bottom of the page. In case of webpages the navigation inside the site should be limited by three clicks
U1	Allow customisation
U2	Try to engage the user
U3	Make adaptive the interaction with users, considering their interaction history, their preferences, requests, and needs
L1	The language should be simple and precise
L2	Acronyms and abbreviations, non-literal text, and jargon should not be used

The accuracy of *graphical layout* is useful to simplify the interaction: layout and content should be predictable. A critical issue is the choice among images,

photographs, and symbolic pictures. What kind of pictures should be included close to the text? A recent paper [54] presents the first study to use eye-tracking technology with a set of adult users with ASD, in order to evaluate text documents with specific features, and it provides specific guidelines for creating accessible text for autism. The text was combined with photographs and symbols. The outcome of the study is that autistic users prefer texts that are paired with images, moreover, both photographs or symbols seem to work well. Note however, that the study was done on a set of adult autistic users without developmental delays. As the authors suggest, this result might be different with children, since the symbolic understanding users with ASD arrives later in their lives compared to neurotypical users.

The study of [42] suggests that for children with developmental delays photographs seem to be more understandable. Other issues are the copious use of pictures and of redundant representation to simplify the concepts absorption. Moreover, pictures should not be used when they are non-relevant or too abstract to help the text comprehension. The *structure and the navigation* should be usable and logic, while the *user* should give space to adaptive personalisation: currently, customisation is applied; engagement is a very important issue. Adaptivity is an open challenge. In order to engage users, in [42] the authors add to the design of a dedicated website some games. These games have resulted into a deep engagement between the users with ASD and the site. On the other hand, [50] introduces the concept of participatory design of user interfaces, i.e., users with ASD highly benefit of personalised interfaces. In this direction interesting results are presented in [42,47], and also in [44], were the authors discuss a participatory design process experimented with four children with autism, to develop their own smart object. The aim and the obtained results were to go beyond functional limitations and to engage the children with ideas, desires and problems. Finally, the use of the *language* should be simple and precise: it is well known that people with ASD literally interpret the text content, and have problems understanding metaphors and abstract sentences.

4 Websites and Dedicated Applications for Users with ASD: A Systematic Comparison

In this section we present a systematic comparison among accessible websites and dedicated applications for people with ASD, and we analyse which and to which extent they follow the guidelines presented in the previous section.

Dedicated Websites for Users with ASD. We have done an extensive search in the Web for sites whose authors have claimed to follow different accessibility standards (e.g., are compliant with W3C standards for HTML and CSS, can be displayed correctly in current browsers. etc.). Although this search is not exhaustive, we have noticed that most of these sites are of autism associations and autism conferences, and are mainly directed to researchers, parents or adults with autism. In next Tables 2 and 3, we refer to all the points mentioned in

Sect. 3. For lack of space, we refer to them as G1 up to G6 for the 6 points of the Graphical Layout; N1 to N3 for the 3 points of the Structure and Navigation; U1 and U2 for the Users, and finally L1 and L2 for the Language. Since **none** of the websites and apps satisfy U3, we avoid to insert this point in our analysis. The outcome can be ● (the guideline has been respected), ○ (no), or ◐ (in part).

Table 2. Implementation of the accessibility guidelines in the current websites.

Websites	G1	G2	G3	G4	G5	G6	N1	N2	N3	U1	U2	L1	L2
[7,8,11]	○	○	○	●	●	○	●	●	○	◐	○	◐	○
[3,13,16]	○	○	○	●	●	◐	●	●	○	◐	○	◐	○
[14,15,25]	○	○	○	●	○	○	●	●	○	●	○	◐	○
[21,22]	○	○	◐	●	●	○	●	●	○	●	○	◐	○
[5,10,18,24]	○	○	◐	●	●	◐	●	●	○	●	○	◐	●
[26]	●	◐	●	●	○	●	●	●	●	●	◐	◐	●
[1,17]	●	●	●	◐	●	◐	●	●	●	●	○	●	●
[4,9]	●	●	●	●	●	◐	●	●	●	●	○	●	●
[42]	●	●	●	◐	●	●	●	●	●	◐	●	●	●

Table 3. Implementation of accessibility guidelines in the current apps.

App	G1	G2	G3	G4	G5	G6	N1	N2	N3	U1	U2	L1	L2
[27]	◐	◐	●	◐	○	○	◐	○	○	◐	●	●	●
[12]	●	●	●	◐	●	◐	●	○	○	◐	●	●	●
[2]	◐	◐	●	◐	●	●	●	●	●	◐	◐	●	●
[19]	◐	◐	●	●	◐	◐	○	◐	◐	◐	○	●	●
[20]	◐	◐	◐	◐	●	◐	◐	●	◐	◐	●	●	●
[6]	◐	◐	●	●	●	◐	◐	○	◐	○	○	●	●
[41]	●	●	●	●	●	●	●	●	●	◐	◐	●	●

While navigating on the sites we have noticed that some of them have similar features, so we have grouped them together. In all these works, we have seen that navigation is consistent, however not very simple. The language is simple in some sections but others connect to many links outside and provide too much information. There is a lot of secondary content inside some pages, and this content is not simple, and there are no feedbacks. [5,10,18,21,22,24] contain many pictures, but not the other sites, the same holds for the text that is short only in [3,5,10,13,16,18,23,24]. [14,15,25] contain some moving text. [7,8,11] lack of images, the general design is not very simple. [3,13,16] have few more images. [26] contains many pictures and tries to engage the user with pictures

and videos. [1,17] follow most of the guidelines, but what they really lack of is the engagement of the user. The sites contain lots of information, in some parts the text is too long, and is accessible for users with ASD which are high functioning, able to read and to communicate. [4,9] respect the graphical layout specifications, however in different parts the text is too long. Navigation is coherent however more buttons and navigation information in the bottom would help. There is no user engagement. The sites mentioned in [42] were designed to follow all the guidelines above presented (except for $U3$). They are the first example of websites explicitly dedicated to users with ASD that independently want to choose their own touring activity close to a specific city (in particular, Rieti and Venice). The sites only lack of adaptivity, and of dynamical customisation of style attributes, on the other hand the users may independently choose different navigational paths depending on their own interests. To engage the user the authors have added games and videos. The sites were tested on a set of users with ASD that have shown their great appreciation.

Thus, to conclude, with the exception of [42], all the websites we have analysed seem to be directed to users which are adults and high functioning (i.e., to users with mild cognitive disabilities), and not to children. Moreover, most of the sites lack of engagement, and all of them of adaptivity.

Dedicated Applications for Users with ASD. Mobile applications represent an important opportunity for users with ASD, as they take advantage of the modality of interactions, like touch screen, and the manageability of the device. Evidence suggests that children with ASD are more engaged and verbal during their use. However, there is a proliferation of commercially available apps, which range from free to very expensive tools: unfortunately this leaves very little room for quality control and the large majority of apps lack any foundation in theory or research evaluation [43]. Obviously, this is a big risk for a vulnerable part of the population.

Table 3 summarises, for a set of current mobile apps, the implementation of the previously listed accessibility guidelines.

A set of apps by *Touch Autism* [27] (like *Social Stories Creator and Library*, *Turn Taker*, *Puzzle Spelling Words*, and others) present some relevant limitations, mainly located in the areas of graphical layout and navigation: for example, *Puzzle Spelling Words* uses an improbable font, starts using a background sound without evident control (it may be interrupted only by the settings panel), does not offer support at the navigation (there are neither navigation buttons, nor exit/pause buttons). In addition, only one set puzzle is free (Playground), while all the others require a payment. *Findme* [12] has been designed at the University of Edinburgh to help children improve their causal and attentions skills. It respects the major part of guidelines, but it does not offer navigation support. The navigation is more complete in the set of *Apps for Autism* by EdNinja [2]: it is possible open a simple visual menu. However, the use of these apps appears to be complex. *Niki Apps* [19] is based a set of apps based on AAC techniques: the apps present different graphical layouts, navigation modalities and styles. The navigation presents some limitations (there are some parts of the app in which it

is difficult find the exit); however, it is possible to draw a sketch but it is not clear where is the saved image and in which way it could be used. Belonging to the same AAC category are the Proloquo apps [20]: *Proloquo4Text* and *Proloquo2Go*. These apps have been created for people who cannot speak, not specifically for people with ASD; they appear too rich of images and content, in contrast with an essential layout. *Autism iHelp Apps* [6] are vocabulary teaching aids developed by parents of a child with Autism and a speech-language pathologist. There are a set of apps: *Same and different*; *Opposites*; *Colors*; etc. They are simple to use and propose concrete pictures, but have some limitations: the navigation is linear and is not possible to return back; the end of an activity is not predictable; and an activity is not reproducible in the same way. Finally, an interesting prototype of mobile app for ASD people is *Volo* [41]; based on AAC techniques, it uses zz-structures, which are hyper-orthogonal, non-hierarchical structures for storing, linking and manipulating data. Summarising, we note that most of the apps provide tools for editing and adding new and eventually personal data, but important limitations involve the process of customisation (often difficult to realise), the user engagement and mainly the lack of user adaptivity.

Some apps use sketched images, other real pictures, most of them provide the user with an initial set of pictures and allow the import of new images from a personal computer, a camera, etc. (see, e.g., [19,27]). Another feature is the possibility of adding *sounds*, which can be synthetic or natural (see, e.g., [31]), or can also be recorded (see, e.g., [19]). Some apps allow the creation of *calendars*: the daily routine might be organised in sequence of actions which describe the activities of the day in a fixed temporal order.

Differently from websites, the apps are conceived for children and they address general issues, not always specifically for people with ASD.

5 Conclusion and Future Challenges

In this paper we discussed possible guidelines for developing accessible websites or mobile applications for users with ASD. We have also analysed and compared many of the existing websites and applications in order to check which comply with all or parts of these guidelines.

As future challenges, we have noticed that all the sites and applications that we have tested lack of a feature that represents an innovative challenge: Adaptivity towards users. Automatically, the systems should be able to adapt their behaviour, considering the history of the users' interaction, their requests, needs and preferences. Another issue is related to the present synthesizers available in different applications. We have noticed that many of them produce sounds which are not easily recognisable by users with limited comprehension. The adaptation of the language and also of the voices would highly improve the quality of these applications. Finally, our future work will be dedicated to refine our proposal of guidelines for ASD accessibility, explicitly considering the usability: accessibility does not imply usability, i.e., a website or an application might be accessible, but not usable. Combining usability and accessibility for new *usable accessibility* guidelines are our next aim.

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