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Accessible and Usable Websites and Mobile Applications for People with Autism Spectrum Disorders: a Comparative Study*

Antonina Dattolo[1,*], Flaminia L. Luccio[2]

[1]SASWEB Lab, DMIF, Università degli Studi di Udine, Gorizia, Italy, antonina.dattolo@uniud.it
[2]DAIS, Università Ca' Foscari Venezia, Venezia, Italy, luccio@unive.it

Abstract

Accessibility, usability and inclusion represent desirable challenges of current research in the field of universal design: in some cases, these features require adaptive behaviours and specialised customisations, while, in general, it is possible to identify common and shareable guidelines. We focus our attention on children with autism spectrum disorders. Many studies show the positive impact of using computer technologies for supporting the lives of these users. Despite that, just a restricted part of the current websites and apps is accessible and usable for people with ASD. In this paper, we present general and shared guidelines and best practices for accessibility and usability for all; and we propose specialised guidelines for designers and developers of websites and mobile applications for users with ASD. We then present a review of many of the existing websites and applications, in order to check which comply with all, or parts of these guidelines.

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1. Introduction

Autism spectrum disorders (ASD) represent a neurobiological condition that significatly impacts behaviour, social communication, social relationships, imagination/rigidity of thoughts [1]. Typical interventions based on the use of Picture Exchange Communication Systems (PECS), aided language stimulation, visual tools and social stories fin in the Web, in mobile devices, in specialised softwares and, in general, in the wide spread of Information and Communication Technologies (ICT) a meaningful opportunity to improve communication, assist the development of social skills, enhance ability to learn of the people with ASD, and not only. In fact, although these users are different one from another, they generally show good abilities in using computer technologies [2], that represent for all, but particularly for them, user-friendly, engaging, multifunctional, portable, easily accessed, and motivating tools.

In this paper, we focus our attention on websites and mobile apps dedicated to children with ASD. There exists a large number of websites, developed by autism associations and autism conferences, but they are mainly directed to researchers, parents or adults with ASD: just a limited number of them is designed for the autonomous use by children with ASD, while the major part of mobile apps satisfie this objective. The question is: when could a mobile app or a website, directed to users with ASD, be considered usable and accessible?

In order to give an answer to this open issue, in this paper, after a brief introduction to the ASD (Section 2), we will define accessibility and usability, identifying the set of current shared guidelines; then, we will discuss, compare and summarise new and existing accessibility and usability guidelines for people with ASD (Section 3). We will then analyse existing websites (Section 4) and mobile applications (Section 5), and compare them, in order to highlight which of them

*Corresponding author. E-mail: antonina.dattolo@uniud.it

comply with all or parts of the guidelines. We will finally discuss, which, in our opinion, are the future trends in the development of usable and accessible technologies for users with ASD (Section 6).

2. The Autism Spectrum Disorder

ASD 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 behaviour, interests, or activities [3].

The *incidence* of this disorder is not negligible. In [4], 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 find 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.

Characteristics of 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*, people with ASD typically 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. The prevalence rate of these language impairments is unclear, however the authors of [5] estimated that 25% – 50% of people with ASD never develop even basic communication skills, which are fundamental for any daily life functionality. 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 [6].

Possible interventions. People with ASD are very different one from another, thus there is no unique therapy that works well for all of them. What is widely shared among all different communities, is that early intervention is crucial, the earliest you discover this disorder, the earliest the family can access specialized interventions, and can understand their kids behaviour and needs. However, the diagnosis is non-trivial, given that ASD is a neurological disorder and not a physical one, i.e., there is no medical procedure to identify it (except obviously for limited known genetic disorders). Thus, the diagnosis is only based on a study of the presence/absence of some specific behaviours (see, e.g., [7, 8]).

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 [9]. 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 [10]. The most common AAC approach is the 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 [11]. 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. Recent studies show the effectiveness of using AAC tools for functional requests by a set us ASD users under the age of 16 [10].

3. Accessibility and Usability Guidelines for Websites and Applications

Many studies show the effective positive impact of using computer technologies to support the lives of users with ASD, in order to simplify interaction with other people, to organise daily activities, to improve relations with family and friends [12, 13].

Moreover, users with ASD present 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 perfectibility 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 [2].

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 customisable with respect to the different users' abilities, and thus targeted to the different skills.

While developing a website, or a mobile application, it is desirable to include an accessibility and usability specialist in the team so to design and then evaluate the results of the design in a proper way [14]. We here focus only on websites and (mobile) applications and discuss possible accessibility and usability guidelines.

3.1. Defining Web accessibility and usability

The goals, approaches, and guidelines of Web accessibility and usability overlap significatly [15]:

- Accessibility addresses discriminatory aspects related to equivalent user experience on the Web for people with disabilities.
- Usability is about effective, efficient, and satisfying design of websites and mobile applications [16].

Accessibility does not imply usability, i.e., a website might be accessible, but not usable. *Usable accessibility* combines together usability and accessibility and produces inclusive design (also called universal design, or design for all), which involves designing products, such as websites, to be usable by everyone to the greatest extent possible, without the need for adaptation.

Accessibility. Users that have physical (visual, auditory, etc.), cognitive or neurological disabilities, children or elderly people are the target users of accessibility features.

Following the definitio of [15] we can state that:

- Accessibility makes users with a wide range of abilities able to *perceive*, *operate*, *interact* and *understand* a user interface.

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 [17].

Moving towards this direction, in 2012 the W3C [18, 19] 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 [20]. 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 [21], however these guidelines are too generic, and not directly targeted to users with ASD, which typically show other specifi problems such as limited attention, sensory hypersensitiveness, limited text comprehension, etc.. They can be a good starting point, but more specifi targeted issues should be taken into account, together with further guidelines that apply to more general computer applications.

In the last years, some work has been devoted to the definitio of guidelines for people with cognitive disabilities [12, 13, 21–25]. However, while dealing with users with ASD with cognitive disabilities, more specifi features have to be taken into account. WCAG 1.0 and WCAG 2.0 [18], which represent the international standard reference model, identify three main features:

- the websites should be clear and simple to use;
- the websites should prevent the users from making mistakes, and, if that happens, make simple to correct them;
- the websites should provide tools for helping the orientation and restore the context, if attention is lost.

In order to satisfy the previous items, they identify, in a very recent document [26] a large set of general techniques, grouped in the following 9 main categories:

1. Use a clear structure;
2. Use an easy to follow writing style;
3. Provide rapid and direct feedback;
4. Help users understanding the content and orientating themselves in the content;
5. Help users to check their work and simplify the undo operation if a mistake occurs;
6. Provide help;
7. Help the user focus and help restore the context if attention is lost;

8. Support adaptability and personalisation;
9. Minimise the cognitive skills required to use the content and avoid barriers.

Starting from previous and different versions of this document [26], other practical and operative guidelines have been proposed [12–14, 22–25, 27–29].

Usability. The definition of usability in the ISO 9241 standard is:

- The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.

Usability is a *quality attribute*, and as stated in [29, 30] is related to *learnability*, i.e., how easy is to navigate for the first time in the site; *efficiency*, i.e., once a user has learned the site, how easy is to accomplish tasks; *satisfaction*, i.e., the user is happy about the website design; *memorability*, the user can remember the site after a period of time; *errors*, how many errors are accomplished while navigating in the site.

Usability is often used as synonym of ease to use; usability means thinking about how and why people use a product; it relies on user-feedback through evaluation; it means a user-centred design, where the users' goals, mental models, tasks and requirements are all met.

In a recent document [31], the U.S. Department of Health & Human Services define some usability research-based guidelines. It provides a detailed list of 208 best practices, grouped in 18 main categories (most of which are self-explanatory):

1. Design process and evaluation (define user requirements, usability goals, meet user's expectations, etc.);
2. Optimising the user experience (provide information and assistance to the user);
3. Accessibility (design forms for users with assistive technologies, test plug-ins and applets, etc.);
4. Hardware and software (design for different browsers, resolutions, etc.);
5. The home page (create a positive first impression of the website, limit homepage length, etc.);
6. Page layout (avoid cluttered displays, optimise display density, use fluid layout, etc.);
7. Navigation (provide navigational options, differentiate and group navigation elements, use site maps and breadcrumb navigation, etc.);
8. Scrolling and paging (eliminate horizontal scrolling, facilitate rapid scrolling while reading, etc.);
9. Headings, titles, and labels (use clear category labels, provide descriptive page titles, etc.);
10. Links (use text for links, provide consistent clickability cues, etc.);
11. Text appearance (use black text on plain, high-contrast backgrounds, etc.);
12. Lists (place important items at top of the list, use static menus, etc.);
13. Screen-based controls - widgets (label pushbuttons clearly, minimise user data entry, etc.);
14. Graphics, images, and multimedia (use simple backgrounds, label clickable images, etc.);
15. Writing Web content (avoid jargon, use familiar words, etc.);
16. Content organisation (use color for grouping, minimise the number of clicks or pages, etc.);
17. Search (ensure usable search results, design search engines to search the entire site, etc.);
18. Usability testing (use an iterative design approach, solicit test participants' comments, etc.).

For each best practice, the document identifies on a 5-point Likert scale, two parameters: the relative importance and the strength of evidence. As we can notice, while accessibility is related to disabilities, usability is a key issue for all users, and it includes accessibility (item 3 in the previous list).

However, during the last years it has been a general agreement on applying a specific user interface (UI) design on the development of webpages and interfaces. The UI design define the user experience by encouraging a natural interaction between the user and the system. A good user experience reflect on the apprecia tion of the tool, and human factors may impact on this, thus it is crucial in the case of users with cognitive disabilities [14, 32].

Since 1996, Jacob Nielsen (the undiscussed guru of usability), and the Nielsen Norman Group have been compiling lists of the top 10 mistakes in Web design. The last document [33] highlights old and persistent problems, in spite of modern design patterns and aesthetics changes; the most relevant are the following:

1. Many websites propone unexpected locations for content, and users cannot use information because they cannot find it;

2. Category and link names do not make sense (poor labelling and poor content differentiation);
3. Small pieces of information is often scattered around the website with little or no connection between these pieces;
4. The users are required to use repetitive links selecting again and again what they want (repetitive links);
5. Often prices and fees are hidden or difficult to find
6. The use of child sites create difficulties to get back to parent site;
7. Poor research results is still a major weakness for many websites;
8. The use of facets and filters does not ensure better usability unless it is introduced to satisfy real needs of users;
9. The pages are overloaded of information;
10. If the links resemble advertising, then they are ignored.

It is meaningful to consider the revolution imposed by the increasing use of mobile applications. In fact, in the 2014, mobile applications have overtaken over fixe Internet access applications. Google itself offers a mobile friendly test [34] to verify for any website if it is responsive or not. This epochal change has a significat impact on two primary aspects of websites:

- Graphical layout and content: mobile content is twice as difficult [35]. Websites should become responsive and hence adapt their visualisations and content to the devices, and also to their orientation (landscape, portrait).
- Touch-based interactions: the traditional interactions with keywords and mouses is substituted by touch-based input in the use of mobile devices; this is a firs critical aspect in the creation of well-adapted user experiences [36, 37].

In March 2016, Google proposed a document [38] which describes general principles of mobile app design: it identifie a set of significat items to consider, as navigation and exploration, search, commerce, and conversions. Finally, it focuses on specifi and app-related design decisions that can be critical for ensuring a good user experience. The following fi e principles are considered essential to design an app that caters to users' needs:

- Speak the same language as your users;
- Provide text labels and visual keys to clarify visual information;
- Be responsive with visual feedback after signifi cant actions;
- Let the user control the level of zoom;
- Ask for permissions in-context.

3.2. Accessibility and usability guidelines for people with ASD

In this section, we try to defin appropriate accessibility and usability guidelines for users with ASD. Obviously these guidelines also take into consideration standard accessibility and usability rules. The specifi guidelines are based on current literature that we have studied, compared and analised on the topic.
From what we have discussed in Section 3, the accessibility and usability features are related to different areas:

- Graphical layout which includes the general design, i.e., text, images, content and how responsive a website or an application is to a connection and if it is resizable, a feature that is fundamental while dealing with mobile devices.
- Another area includes the structure and navigation which are fundamental while dealing with users with cognitive impairments (i.e., for accessibility) and also for users' satisfaction (usability).
- A crucial and non-trivial aspect is how to interface with a user: engagement, customisation, and adaptivity are all very important features to allow the user to focus on the topic and to be satisfied
- Finally, the language is a key issue while dealing with impaired users.

Following these crucial aspects we summarise in Table 1 the proposed guidelines, divided in four macro-areas: graphical layout, structure and navigation, user and language (indicated respectively by G1-G7, N1-N4, U1-U5, L1-L2).

The accuracy of *graphical layout* is useful to simplify the interaction: layout and content should be predictable. The study of Darejeh et al. [24] investigates general usability principles that can be succesfull y applied also to users with mental disorders and autism. For such users, the general suggestion is to reduce the number of features available at any time instant, and to design interfaces where tools can be found immediately, without any investigation.

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

Table 1. Accessibility and usability 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. The number of features available at any time instant should be limited.
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.
G7	The interface should be responsive.
N1	Navigation should be consistent and similar in every page/section.
N2	The website and every mobile applications should have a simple and logical structure. Even the first time, the user should be able to easily navigate inside, and should remember the navigational information even at successive visits or uses.
N3	Add navigation information and navigation buttons at the top and the bottom of the page.
N4	Efficiency and availability.
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.
U4	Decompose the tasks into simple subtasks.
U5	The number of errors should be limited.
L1	The language should be simple and precise.
L2	Acronyms and abbreviations, non-literal text, and jargon should not be used.

paper [39] 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 neuro-typical users. The work [23] 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. Finally, a general and fundamental aspect is the adaptation of the graphical layout to any device, to its orientation, and to the dimensions of the Web browser windows: the graphical interface should be responsive.

The *structure and the navigation* should be simple, consistent and logic. The users should find all the navigational buttons and all the necessary tools in a immediate way. In case of webpages, the navigation inside the site should be limited by three clicks, links should not be broken. The site should be responsive, i.e. connection should be fast and windows should be resizable.

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 [23] 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, [14] introduces the concept of participatory design of user interfaces, i.e., users with ASD highly benefi of personalised interfaces. In this direction we find interesting results in [23, 40], and also in [41], were the authors discuss a participatory design process experimented with four children with autism, to develop their own smart object. The aim and the results were to go beyond functional limitations and to engage the children with ideas, desires and problems. Thus, if the uses are engage, they will be willing to revisit the site o reuse a certain application.

From the usability point of view, in the development of webpages, Tarpin-Bernard et al. in [42] propose an environment, called the *Cognitive User Modelling for Adaptive Presentation Of Hyper-Documents (CUMAPH)*,

used to adapt the webpages to the user's profile. The adaptation is based on four specific sectors such as: attention, memory, language and visuospatial, and from them some cognitive indicators are extracted and used to adapt the webpage. Regarding software tools, in [32] the authors propose the use of Adaptive User Interfaces (AUI's), in order to adapt the system to the specific user. To develop these interfaces they build the interactions rules of the user with the software, based on the *Executive Functions*. These functions regulate several cognitive aspects such as cognitive flexibility, planning, working memory, inhibition, and sustained attention, which are strictly related to the cognitive processes used to accomplish tasks. What the experimental results show is that the way the application *decomposes the task* seems to mostly affect the usability since when properly done it decreases the cognitive load on the user. This decomposition allows the user to easily accomplish the tasks.

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 for Users with ASD: a Systematic Comparison

In this section we present a systematic comparison among accessible and usable websites for people with ASD, and we summarise in two separate tables which comply with all, or parts of guidelines presented in previous Section 3.

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 they are mainly directed to researchers, parents or adults with autism.

In the following Tables 2 and 3, we refer to all the points mentioned in Section 3 regarding both accessibility and usability features. We refer to them as G1 up to G7 for the 7 points of the Graphical Layout; N1 to N4 for the 4 points of the Structure and Navigation; U1 to U5 for the Users, and finaly 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 ◐ (partially).

While navigating on the sites we have noticed that some of them have similar features, e.g., we have seen that in all of them 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. Tasks are not divided unto subtasks except in few sites. [52–57] contain many pictures, but not the other sites, the same holds for the text that is short only in [46–48, 54–57, 63]. [49–51] contain some moving text. [43–45] lack of images, the general design is not very simple. [46–48] have few more images. [58] contains many pictures and tries to engage the user with pictures and videos. [59, 60] follow most of the guidelines, but what they really lack of is the engagement of the user and the subdivision in sub-tasks. 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. [61, 62] 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. Most of the websites are available, there are few exceptions of sites that contain some broken links. Some websites are not resizable, thus do not work properly on mobile devices. The sites mentioned in [23] 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.

Summarising, with the exception of [23], 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, responsiveness, subdivision of tasks, and all of them of adaptivity.

5. Dedicated Applications for Users with ASD: a Systematic Comparison

Mobile applications represent an important opportunity for users with ASD, as they may take advantage of the modality of interaction, e.g., the use of 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

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

Websites	G1	G2	G3	G4	G5	G6	G7	N1	N2	N3	N4	U1	U2	U4	U5	L1	L2
[43]	○	○	○	●	●	○	○	●	●	○	◐	◐	○	○	◐	◐	○
[44]	○	○	○	●	●	○	○	●	●	○	●	◐	○	○	●	◐	○
[45]	○	○	○	●	●	○	●	●	●	○	●	◐	○	○	●	◐	○
[46]	○	○	○	●	●	◐	○	●	●	○	●	◐	○	○	●	◐	○
[47]	○	○	○	●	●	◐	●	●	●	○	●	◐	○	◐	●	◐	○
[48]	○	○	○	●	●	◐	●	●	●	○	●	◐	○	○	●	◐	○
[49]	○	○	○	●	○	○	●	●	●	○	●	●	○	○	●	◐	○
[50]	○	○	○	●	○	○	○	●	●	○	●	●	○	○	●	◐	○
[51]	○	○	○	●	○	○	○	●	●	○	●	●	○	◐	●	◐	○
[52, 53]	○	○	◐	●	●	○	●	●	●	○	●	●	○	○	●	◐	○
[54, 55]	○	○	◐	●	●	◐	●	●	●	○	●	●	○	◐	●	◐	●
[56]	○	○	◐	●	●	◐	●	●	●	○	●	●	○	○	●	◐	●
[57]	○	○	◐	●	●	◐	○	●	●	○	●	●	○	○	●	◐	●
[58]	●	◐	●	●	○	●	●	●	●	●	●	●	◐	○	●	◐	●
[59, 60]	●	●	●	◐	●	◐	●	●	●	●	●	●	○	○	●	●	●
[61]	●	●	●	●	●	◐	●	●	●	●	●	●	○	◐	●	●	●
[62]	●	●	●	●	●	◐	●	●	●	●	●	●	○	○	●	●	●
[23]	●	●	●	◐	●	●	●	●	●	●	●	◐	●	●	●	●	●

little room for quality control and the large majority of apps lack any foundation in theory or research evaluation [71]. 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 and usability guidelines. The guideline G7 is not included, since all the apps satisfy this point.

A set of apps by *Touch Autism* [64] (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 of puzzles is free (Playground), while all the others require a payment. *Findme* [65] 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 [66]: it is possible open a simple visual menu. However, the use of these apps appears to be complex. *Niki Apps* [67] is based on 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 [68]: *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* [69] 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 they have some limits: the navigation is linear and is not possible to return back; the conclusion of any activity is not predictable; the activities are not reproducible in the same way. Finally, the prototype of mobile app for ASD people is *Volo* [70]; based on AAC techniques, it uses zz-structures, which are hyper-orthogonal, non-hierarchical structures for storing, linking and manipulating data. This prototype has

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

Apps	G1	G2	G3	G4	G5	G6	N1	N2	N3	N4	U1	U2	U4	U5	L1	L2
[64]	◐	◐	●	◐	○	○	◐	○	○	◐	◐	●	◐	○	●	●
[65]	●	●	●	◐	●	◐	●	○	○	●	◐	●	●	●	●	●
[66]	◐	◐	●	◐	●	●	●	●	●	◐	◐	◐	●	●	●	●
[67]	◐	◐	●	●	◐	◐	○	◐	◐	●	◐	○	●	●	●	●
[68]	◐	◐	◐	◐	●	◐	◐	●	◐	◐	◐	●	◐	◐	●	●
[69]	◐	◐	●	●	●	◐	◐	○	◐	●	○	○	●	○	●	●
[70]	●	●	●	●	●	●	●	●	●	●	◐	◐	●	●	●	●

been modelled in order to be accessible and usable, the aspects related to the user customisation and engagement could be improved.

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., [64, 67]). Another feature is the possibility of adding *sounds*, which can be synthetic or natural (see, e.g., [72]), or can also be recorded (see, e.g., [67]). 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 fixe temporal order.

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

6. Conclusion and Future Challenges

In this paper, we discussed about possible guidelines for developing accessible and usable 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. Regarding usability, responsiveness is often neglected and very few websites take into account the division in subtasks. These features are very important and non-trivial. Another issue is related to the present synthesisers 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.

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