Accessible Conversational User Interfaces: Considerations for design

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Considerations for design

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ABSTRACT

Conversational user interfaces (CUIs), such as chatbots and voice assistants, are increasingly common in areas of day-to-day life, and can be expected to become ever more pervasive in the future. These interfaces are being designed for ever more complex interactions, and they appear to have potential to be beneficial to people with disabilities to interact through the web and with technologies embedded in the environment. However, to fulfil this promise they need to be designed to be accessible.

This paper reviews a range of current guidance, reports, research and literature on accessible design for different disability groups, including users with mental health issues, autism, health conditions, cognitive disabilities, dyslexia or learning difficulties, and sensory, mobility or dexterity impairments. We collate the elements from this body of guidance that appear relevant to the design of accessible CUIs, and instances where guidance presents issues which are less conclusive, and require further exploration. Using this, we develop a set of questions which could be useful in the further research and development of accessible CUIs. We conclude by considering why CUIs could present opportunities for furthering accessibility, by introducing an example of this potential – a project to design an assistant to support students to disclose their disabilities and organise support, without the need to fill in forms.

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Conversational user interfaces, accessibility, chatbots, virtual assistants, AI

1 Introduction

Conversational user interfaces (CUIs), including Artificial intelligence (AI) assistants, voice activated personal assistants (VAPAs) and chatbots, are becoming common in day-to-day life. Virtual Customer Assistant chatbots are expected to be implemented by 25% of organisations in 2020, in order to more efficiently serve customers [1]. Voice assistants, such as Amazon Alexa, are a common consumer product in the home [2] and similar interfaces are being used in other spaces such as cars [3]. As CUIs become pervasive, they should be an important concern for the accessibility field. Equally, CUIs are instrumental in enabling a shift towards a different style of interaction, one which has the potential to be beneficial for users with a wide range of disabilities. Despite this, there is very little guidance on how to design and develop accessible CUIs, particularly for disabilities such as cognitive disabilities, mental health issues, autism, or specific learning difficulties, such as dyslexia.

This paper takes initial steps in addressing the gap in understanding by reviewing a range of guidance, reports, research and literature on accessible web design and design for different disability groups. Through this, we collate guidance relevant to the design of accessible CUIs and identify key accessibility considerations that should be taken into account when designing them. The paper provides a set of questions that represent areas for consideration in design and further exploration in research.

2 Conversational User Interfaces

CUI is used as a collective term for a variety of assistants that mimic human conversation. For the purpose of this paper, we use this term broadly to include voice-activated personal assistants such as Amazon Alexa, virtual assistants such as Apple Siri, and chatbots, such as Spot or Mitsuku. It is notable that a wide variety of terminology is used to describe systems in this area, and that this has not been applied consistently in literature. While there are important distinctions between CUI designs, there is substantial overlap and potential for further convergence between these systems, and many of the accessibility issues are relevant across the breadth of designs.

Before we highlight key features of these systems from literature, we first map the landscape of common CUIs in terms of their main types:

- Chatbots are a common form of CUI with a substantial history of development. They are defined as conversation systems that interact with human users via natural language [4]. Common uses of these include customer service, entertainment and therapy. Chatbots are often interacted with through text chat, but spoken dialogue with these systems is also possible.
- Interactive Voice Response (IVR) systems are a further form of mainstream CUI, which are commonly used in telecommunications systems where organisations deal with large call volumes. These tend to be relatively limited, commonly using pre-recorded audio and specified response options [5].
- 'Virtual assistants' such as Microsoft's Cortana and Apple's Siri share the foundation of natural language and conversation with chatbots, although they have a more specific role to play in helping the user. Virtual assistants for general use are embedded in smartphones and within operating systems, and are used to interact with these devices and with various services, such as interacting with a calendar or telling the user a weather forecast. Virtual assistants have also been designed and evaluated for more specific audiences, including to help those with cognitive impairments with their daily routine and calendar events [6]
- Voice-activated personal assistants (VAPAs) are virtual assistants that operate through dedicated hardware devices such as voice-activated smart speakers and in-car voice-based assistants. These are sometimes also referred to as Voice User Interfaces (VUIs). Some such systems are specialised for interactions in the home (e.g. Amazon Alexa) and to control smart home devices such as lighting. [7,8]. Others, such as Google Assistant, can be used across a variety of devices including phones and dedicated hardware devices.

2.1 Features of CUIs

In this section we identify key features of CUIs that distinguish them from other interfaces and could be relevant in their accessibility.

2.1.1 Potential for multiple communication modalities

Dialogue is fundamental to CUIs, but this may occur across one or multiple modalities. The underlying technologies are similar. For example, McTear [9] introduces the components of spoken dialogue technologies as speech recognition, language understanding, dialogue management, communication with an external source such as a database, language generation and speech synthesis. However, if the speech recognition and speech synthesis steps were replaced, this set of components could adequately describe interactions such as those with a text-based chatbot.

While CUI research and development has often focused on one communication modality, such as text or speech, there has been some convergence in systems towards CUIs that have a combination of visual, text-based, and graphical components, and may also make use of buttons or other GUI components as part of the dialogue.

Schaffer and Reithinger [10] argue that CUIs should be multimodal, specifically including non-verbal communications, because conversations between users may include elements such as body language. Conversely, many chatbots in use contain hybrid interfaces, where dialogue occurs with a combination of media and interactive rich messaging features such as quizzes, media and app-like widgets [11].

2.1.2 Potential for use through multiple channels

Chatbots and other CUIs can be integrated with one or several different channels. A channel in this context refers to first- or third-party web and software applications, and examples of channels include Facebook Messenger, Slack, Skype, and web chat. Brandtzæg [4] notes that users are spending increasing time using messaging platforms such as the above, and that because these platforms are based in text conversation, they are becoming a setting where chatbots are fundamental to interacting with audiences.

The accessibility of a chatbot to different audiences will, in significant part, be determined by the channel. For example, a mobile app for a specific messaging platform may already be accessible to screen reader users, or the app may constitute a significant barrier to screen reader users. The overall accessibility of a CUI experience could be the summation of the accessibility of the channel, and the accessibility of the CUI itself. The channel will have an influence over technical and visual-design aspects of accessibility, for example colour contrast, font-size, description and navigation of hyperlinks, buttons and other visual elements, how assistive technology is notified when new content is added, and so on. The CUI has influence over the design and use of content, for example, use or misuse of jargon, abbreviations, and confusing language. The CUI may also be the source of media content for which accessibility issues could arise. Either could present and control accessibility-related options and features.

2.1.3 Dialogue-based interactions

As CUIs are based around exchange of utterances in a dialogue, the way in which these interactions unfold over time, and the expectations around taking turns or the initiative over time, are a fundamental difference to GUIs. Rather, by focusing on statements and responses made in turn, CUIs have similarities with command line interfaces [11], which have been superseded by GUI in most areas of computing. Interaction with a CUI follows a similar structure to the command line. The choices or actions available may be less apparent to the user of a CUI.

CUIs can involve quick and specific tasks, or long-term relationships [4]. Glass et al. [12] distinguish 'directed-dialogue' applications in which users answer prescribed questions and have more restricted options in response, with more complex 'mixed-initiative dialogue' applications which are more flexible and allow a conversation to be directed by both user and AI. IVR systems for telecommunications could be a form of directed-dialogue system that has reached mainstream use. Mixed initiative systems are considered more complex to create. Indeed Glass et al. argued in 2005 that "systems that learn and improve their performance automatically" are needed for these systems to work [12].

CUIs are still developing and may become more able to engage in human-like conversations as the technology advances. Equally, differences could remain in how humans engage in conversation with these systems when compared to other humans, as current research suggests. Hill et al. [13] found that human-chatbot conversations were longer in duration, but used shorter messages, and a more limited vocabulary. Conversely however, there is evidence that some of the emotional, relational and psychological benefits of personal conversations can be replicated with CUIs [14]

2.1.4 Combining logic and machine learning

Many modern CUIs combine rule-based logic and statistical machine learning algorithms [15]. As with other AI systems, bias introduced by the data used to train the AI, or in the algorithms developed, and shortcomings in interpretation, may create inequities between users. These are likely to be particularly problematic for users such as those with a specific disability affecting a minority of users [16], who may not be represented in training data or in the design process. Aside from processes through which CUIs can learn how to interpret and respond to human utterances, systems are coded, and logic generated to create a basis for designing a conversation and achieving particular goals. This logic may also not be designed with a diverse user base in mind.

Given the requirement to interpret diverse human input, and the potential for a lack of clarity as to what a CUI is capable of or the commands open to a user, an important element of designing CUIs is the capacity to deal with situations in which the system is uncertain of the correct response, or has made an incorrect response. CUIs can set expectations, for example by showing the user how the CUI has interpreted their input or making explicit the accuracy or confidence held in this interpretation [17].

2.2 Accessibility and CUIs

Research on the usability evaluation of chatbots suggests that users can quickly become proficient in using these interfaces, but that different approaches may be needed, and problems may take more participants to identify, when compared to GUIs [18]. Similar differences may exist for accessibility evaluations; we could envisage CUI interactions that are intuitive and accessible, but there could also be accessibility problems that are distinct from the types found in GUIs.

The inherent adaptability of CUI systems to work through multiple communication modalities such as text or audio has potential to support universal access. For example, voice interfaces can make it easier to control technologies around the home or other spaces [8]. In many cases, particularly for users with any visual impairment, dialogue can be more appropriate, where the layout of these complicates use and requires assistive technology. CUIs could counter the 'pervasiveness of Graphic User Interfaces (GUIs) in most contemporary computing systems' [19] and the inequalities of experience this has engendered. If assistive technology (AT) is designed as instruction and response based, a CUI could mirror this without the need for AT, creating potentially a more natural transaction than using AT with a GUI. Additionally, dialogue can be a more 'natural' way to communicate for users with cognitive disabilities or dyslexia; advances in natural language processing can transform textual content and reduce cognitive load in users [20]. Conversation can also be a better medium than static interfaces, such as forms, when the activity requires both parties to understand each other. The administrative burden on disabled users from form filling has been found to be high [21], and we are exploring the opportunities for CUIs to lighten this load.

However, for this potential to be realised, accessibility for users with disabilities needs to be designed in. Accessibility issues with CUIs have been highlighted [7], but there is comparatively little guidance in this area. Given the potential for multiple ways of interaction with a CUI described in the previous section, accessibility testing may need to be conducted and documented in the context of a specific combination of CUIs, channels and modalities. Equally, designers and developers should be supported to consider accessibility when creating CUIs, particularly in areas where this differs fundamentally from how accessibility is achieved in a GUI.

This paper takes initial steps in addressing the gap in understanding, by reviewing a range of sources on accessible Web design, identifying the key accessibility considerations relevant to CUIs, and presenting these as issues and opportunities to be explored further.

3 Methodology

In this section we define the methodology which includes the sources of guidance and the disability classifications used in the review.

3.1 Sources of guidance

In creating these recommendations, we review and bring together a range of resources, including web accessibility guidance, research publications, reports, literature and commentaries. The sources drawn on are listed and categorised in table 1, below:

Table 1: Sources used in review

Author(s)	**Year**	**Description**	**Type of source**	**Disability categories**
Kirkpatrick et al	2018	WCAG 2.1	Guidance	General or multiple
Pun et al	2016	Gov.uk accessibility posters	Guidance	General or multiple
Abou-Zahra et al	2017	Web Standards to Enable an Accessible and Inclusive Internet of Things (IoT)	Journal article	General or multiple
Kushalnagar	2019	'Deafness and Hearing Loss': chapter in *Web Accessibility; A Foundation for Research*	Book chapter	Hearing impairment
Barreto and Hollier	2019	'Visual Disabilities: chapter in *Web Accessibility; A Foundation for Research*	Book chapter	Visual impairment
Abdolrahmani et al	2018	'Siri talks at you'	Journal article	Visual impairment, cognitive disabilities
Trewin	2019	'Physical Disabilities: chapter in *Web Accessibility; A Foundation for Research*	Book chapter	Mobility impairment
Swallow	2018	'Accessibility for people with anxiety and panic disorders', Paciello group	Blog posts 1 & 2	Mental health
Thielsch & Thielsch	2018	Depressive symptoms and web user experience	Journal article	Mental health
Harris	2017	How to design for people struggling with mental health	Blog post	Mental health
Vaidyam et al	2019	Chatbots and conversational agents in mental health	Journal article	Mental health
Seeman and Lewis	2019	'Cognitive and Learning Disabilities': chapter in *Web Accessibility; A Foundation for Research*	Book chapter	Cognitive disabilities, mental health
Budiu and Laubheimer	2018	Intelligent Assistants Have Poor Usability	Online article	Cognitive disabilities
Roper et al	2019	'Speech and language': chapter in *Web Accessibility; A Foundation for Research*	Book chapter	Cognitive disabilities, speech and language
Atherton	2018	'Cognitive difficulties' blog post on *UX Collective*	Blog post	Cognitive disabilities
Mance Calisir et al	2018	Cognitive Features of High-Functioning Adults with Autism and Schizophrenia Spectrum Disorders	Journal article	Autism
Dattolo et al	2016	Web accessibility recommendations for the design of tourism websites for people with autism spectrum disorders	Journal article	Autism
Autism.org	2019	Designing Autism-friendly websites	Guidance	Autism
Robertson & Baron-Cohen	2017	Sensory perception in autism	Journal article	Autism
Bradley & Caldwell	2013	Promoting autism favourable environments	Guidance	Autism
Nguyen	2006	Creating an Autism Friendly Environment	Guidance	Autism
Walker	2017	How Artificial Intelligence is empowering people on the autism spectrum: Ability Net	Blog post	Autism
Ross et al	2013	What is brain fog?	Journal article	Medical/pain/fatigue
Kravitz & Katz	2015	Fibrofog and fibromyalgia	Journal article	Medical/pain/fatigue
Ocon	2013	Caught in the thickness of brain fog	Journal article	Medical/pain/fatigue
Chan	1999	Review of common management strategies for fatigue in multiple sclerosis	Journal article	Medical/pain/fatigue
De Santana et al	2012	Web accessibility and people with dyslexia	Journal article	Dyslexia & SpLD
Williams	2017	5 ways to make your Website or App Accessible for people with ADHD	Blog post	Dyslexia & SpLD
Mace	1985	Universal design: Barrier free environments for everyone.	Journal article	General or multiple

3.2 Categories of disability

Our review included a broad range of accessibility guidance devised for different types of disability. However, disability categories are not static; the United Nations provides umbrella categories of 'physical, mental, intellectual or sensory impairments' [22], but more detailed categories of disability generally vary according to context. For this paper, we have consulted categories suggested in legislative [23], medical [24] and educational [25] contexts, in conjunction with the categories listed in our sources, and have compiled the following list of disability categories to act as a framework:

1. Deaf or hearing impairment
2. Visual impairment
3. Mobility/dexterity impairment
4. Mental health
5. Cognitive and learning disabilities
6. Autism spectrum conditions
7. Long term fatigue, pain or health conditions
8. Speech impairment
9. Dyslexia and specific learning difficulties

These categories provide a schema to structure the review and ensure breadth of coverage, while providing contextual information on how issues may impact particular users. In some literature, autism spectrum conditions, dyslexia or mental health issues may be categorised differently, e.g. as cognitive disabilities [26]. However, although these conditions affect cognitive function, they do not necessarily impair it [27, 28, 29, 30], and their accessibility requirements are sufficiently different that we believe these groups require individual categories. This distinction is also made in the education sector [25], and we follow this precedent for our model.

4 Findings

In this section we discuss our review. We begin with general guidance (for which WCAG 2.1 was specified in the previous section), we continue according to the schema of disability categories identified in section 3.2, and finish with a consideration of Universal Design principles.

4.1 Applicability of general guidance (WCAG)

The relevance of the Web Content Accessibility Guidelines (WCAG) to CUIs is important to assess. WCAG aims to serve the needs of most of the groups mentioned above, but with regards to web design and related mobile interaction design. Here we highlight elements of WCAG 2.1 that were found to be particularly relevant, or in which the interpretation of which is unclear, with regards to CUI designs [31].

4.1.1 Perceivable

All elements of CUI dialogue must be available to a user according to their available senses. Most success criteria relating to perception are readily adaptable to this goal. The application of the success criteria 1.3.2 'meaningful sequence' is particularly interesting in the case of CUIs. This could be adapted by suggesting that the ordering of the conversation and its history should be accessible to the user as a priority.

It is less obvious how success criteria 1.3.5 should be adapted to CUIs. Unlike a web form, the way in which a user could identify the 'purpose' of giving a textual or spoken response to a CUI is not clear. This purpose would depend on the current context, which could be made clear through instruction from the CUI or from surrounding information.

4.1.2 Operable

The operation of a CUI is dependent on the available communication modalities and (if applicable) the channel through which it is presented. If speech and audio are used, the capability to understand the user's voice with accuracy is clearly essential to accessibility. As suggested by guideline 2.1 and related success criteria, where keyboard or touch navigation is used, this needs to be accessible. The behaviour of the keyboard focus is important to assess in the design of the conversational flow and may be a source of tension. E.g. how does a user switch between inputting a message and reading messages from a chatbot as they arrive?

Guideline 2.2, 'enough time' could require additional thought in conversation design. Designers may consider how a CUI can adapt or be controlled by the user in order that it allows appropriate time for their responses but does not leave them unaided where an interjection could be helpful.

Making a CUI 'navigable' (guideline 2.4) is a further area where adapted guidance appears to be needed. As noted above, one of the benefits of GUIs that can be lost in CUIs is the ability to present a visual understanding of user choices and affordances. However, research and development into accessible CUI design may be useful for users who do not benefit from the visual GUI approach to navigation. In some CUIs, the users' 'location' in a series of steps to complete to achieve a goal may be very important. In other cases, conversational designs may not have locations or states that are navigated to or away from.

4.1.3 Understandable

In making CUIs understandable, guideline 3.2 of 'predictability' appears problematic, particularly for AI-based CUIs. Conversations could be expected to progress rather than returning to the same responses given the same input. Training of systems to become more capable of human-like conversation and knowledge may lead to unexpected responses, or to over-inflated expectations of what the CUI will do.

The focus on error identification, suggestion, and prevention in guideline 3.3 should be suitable for adaptation to CUIs, but the nature of the errors and their frequency in a situation based in machine interpretation of natural language responses are quite distinct from the errors expected in web-based text fields. CUIs should be capable of context sensitive help on the actions that users are trying to undertake, but the user must be made aware of how to access this.

4.1.4 Robust

The compatibility of assistive technologies with CUIs, which constitute dynamic interactive systems, is clearly an important area for attention. CUIs could use existing web-based standards to provide accessibility features, such as alt-text or captioning. However, as noted in the section on the Operable principle, the flow of a CUI interaction may be quite different to the flow of an interaction with a web page.

4.2 Deaf / hearing impairment

For deaf or users with hearing impairments, text-based chatbots could offer a convenient alternative to telephone contact with organisations. However, a visual element is essential to this, with either a text-based interface or a captioned voice assistant [31, 32]. There must therefore be a visual option for CUIs, supporting the full breadth of functionality. Presently, voice-based assistants and IVR systems exist that do not offer text or visual based alternatives. If the CUI provides links to additional or third-party content, it should be able to 'carry forward' [8] accessibility settings and these in order to not provide resources that are inaccessible to the user.

4.3 Visual impairment

The conversational nature of voice-activated CUIs, in which visual communication modalities are often less fundamental, make them 'ideal for users with vision disabilities to find information and request actions' [19]. However, chatbots in particular can present accessibility challenges.

Visual or text-based CUIs should have an audio version and / or should be accessible for use with a screen reader [19]. This is the case for both a mobile and desktop environment [7]. In addition to this, in text-based CUIs, the user should have ability to change the font size and the colour of both the text and the background [19, 31], and should be able to magnify the screen 'up to 200 percent without loss of content or functionality' [31].

User agency is an important element of accessible design; users 'must be able to use the assistive technologies they need on their device of choice.' [19]. A complexity is created in 'hybrid' CUIs that use rich messaging features and widgets. Here there is potential that these components are inaccessible even if the basic platform is. If the CUI links to or embeds additional or third-party content, it should be able to support the use of these, or be able to recognize and filter content, in order to serve the user without providing them with resources that are inaccessible.

4.4 Mobility / dexterity impairment

Users with mobility or dexterity impairments can find small buttons or using a mouse challenging or may experience pain or difficulty from repeated or sustained activity [33]. A voice-activated CUI therefore provides an opportunity for improved accessibility to services by reducing the need for physical interaction e.g. through a mouse or keyboard. However, some audiences of users with mobility/dexterity impairments may also have speech impairments; for example, both speech and dexterity may be affected by a stroke [33].

There may be scenarios such as stroke where a text-based interface with good keyboard accessibility is appropriate. This should include a clear visual focus [31], or a touchscreen interface [33]. The size of buttons – whether part of a hybrid CUI interface, or an onscreen keyboard - should be considered as part of the design, as small buttons present particular challenges for this group [33]; ideally, button size should be adaptable as part of user preferences [31].

Text interfaces should also have a slow or adaptable time-out feature, as users with dexterity impairments may type more slowly than anticipated [31,33]. Finally, designers should attempt to avoid the necessity of periods of sustained activity e.g. scrolling [33].

In conclusion, hybrid CUIs, which can use of multiple communication modalities of input or embed GUI elements, are an area for attention for users with mobility / dexterity impairments. Adaptable CUIs, and voice-based CUIs specifically, may present important opportunities for this group.

4.5 Mental health

Guidance on designing for users with mental health issues is not frequently mentioned explicitly in accessibility guidance, (although Swallow notes that some of the success criteria in guidance such as WCAG [34] is beneficial for these users.) However, mental health can affect user experience in a variety of ways; Swallow [35] lists design principles for users with anxiety, Thielsch and Thielsch [36] investigate the impact of depressive symptoms on web user experience, and Harris [37] reports Sigma's findings from designing the mental health charity Mind's website. As therapy chatbots, designed specifically for users with mental health issues, are becoming increasingly prevalent [38], this is a key area of consideration in accessible design.

Thielsch and Thielsch [36] found a statistically significant correlation between depressive symptoms and negative user experience of websites, implying that general issues with usability that may be encountered by all users have a more profound impact on users with depression [36]. This is similar to findings reported for users with cognitive disabilities [20] and implies that usability issues may become accessibility issues for this group of users.

Swallow highlights the need to reduce 'panic triggers' for users with anxiety [34]. Good practice applicable to CUI design includes to ensure users have enough time to formulate questions or responses without excessive or intrusive prompting; the need for 'subtle notifications' instead of 'intrusive and demanding' ones; and the need to ensure users are clear on what they are experiencing and what (if anything) will happen next as a result of their interaction. Both Swallow and Harris comment on the importance of aesthetics, including areas such as typography and use of colour, overall clean design, keeping instructions and interface clear and clean, and the need to reduce 'cognitive load' in terms of presenting information in a calming way.

Swallow also discusses interesting uses of 'friction' in design. Usually reducing friction (i.e. 'anything that prevents users from accomplishing a task') is desirable for users with mental health issues, as friction can create a 'sense of powerlessness' or frustration and can trigger anxiety or depression. However, Swallow lists cases in which friction can be helpful for users with mental health issues, such as 'letting users check their answers before they submit them', and the case of an online bank that prototyped a functionality of delaying and requesting user confirmation for bipolar users making late-night impulse purchases [35]. Both of these cases could be applied in the design of CUIs, and there is a clear need to investigate other areas where the reduction or application of friction can be beneficial for users with mental health issues.

4.6 Cognitive and learning disabilities

The title 'cognitive and learning disabilities' spans a broad range of issues that impair cognitive function and impact on user experience. Examples include dementia, Down's syndrome and brain injury, and may include impacts on memory, executive functions, planning/organisation, judgement and reasoning, and other areas [20]. As with mental health, research has shown that 'the problems encountered by many users with cognitive disabilities are, broadly, the same usability problems that affect all users, but the impact on users with cognitive disabilities is more severe' [20].

Budiu and Laubheimer [39] critique the usability of CUIs, noting in particular that users may not know what questions to ask, and suggesting that CUIs should provide hints and tips, and should not require precise phrase recall [39]. Roper et al emphasise the need to 'Keep text short and simple' [40], Seeman and Lewis mark the need for clear, understandable speech [20], and for designers to allow for delays in response and 'let users control the pace of the interaction' [40]. Roper et al recommend designers 'minimise distractions' and 'Limit the number of steps' [40], and Atherton says, 'give users as few choices as possible, presented one by one' [41], so they are not overwhelmed or confused. WCAG guidance marks the need to ensure that any 'error identification', or in the case of CUIs, non-comprehension responses, are clear [31]. Finally, unexpected or involuntary activation of the CUI (such as VAPAs being activated by television advertisements) should be avoided, as this can be confusing or distressing [7].

4.7 Autism spectrum conditions

As noted, in this paper we classify autism spectrum conditions (ASC) as a separate category from cognitive disabilities, as autism does not necessarily impair cognitive function (although it does affect it). Indeed, Mance Calisir et al found that cognitive function in adults with high functioning autism 'could be higher than average in situations that do not involve social interaction' [30]. However, differences with sensory perception and communication autistic users experience are key accessibility considerations [42, 43, 44]

As with other disability categories, the need for 'clean and uncluttered design' [43] and clearly labelled buttons [45] in a CUI is important. The risk of sensory overstimulation is an accessibility concern for autistic users, so colour palettes should involve 'low arousal' background colours, such as cream and other pastels, but ideally not yellow or white [46, 47]

Language is important; designers should avoid 'figures of speech and idioms' [48], 'exaggeration, ambiguous language or turns of phrase that may have more than one meaning'.

Transparency is also a key accessibility issue for conversation design; it is important that the CUI clearly states its nature and does not aim to impersonate a human, clearly informs the user what will happen with any data they have shared and manages expectations about any outcomes from the conversation. Designers should, as far as possible, create an interface that allows the user to be in control of their data and the conversation.

4.8 Long term health, fatigue or pain conditions

Long-term medical conditions, including cancer, diabetes, epilepsy, or crohn's disease, are classified as disabilities and can have a significant impact on a user's web experience. In some disability classifications, conditions causing fatigue and/or pain, such as arthritis, chronic fatigue syndrome, fibromyalgia or chronic migraine, are classified as a separate category. However, although every condition and user's web experience will be different, there are commonalities to be found in the accessibility requirements for these groups, so we have classified them as a single category.

Many users with long-term medical conditions report brain fog, either as a result of their condition or their medication [49, 50, 51]. The guidance for designing for brain fog is broadly similar to designing for cognitive disabilities and in line with WCAG [20, 31]; enable voice or text interaction, ensure interface is uncluttered and steps and instructions are clear. Users also report screen fatigue [52] so there is a need to enable users to change colour scheme, especially for conditions like chronic migraine, and to ensure there is sufficient colour contrast and a clear font. For users with epilepsy, there should be no flashing content or contrasting light and dark patterns. In some situations, these issues could be resolved by supporting speech-based input as an alternative to a visual, text-based interface.

Overall, however, there is little research about accessibility for this group of users, and more research is needed to better understand their requirements [53].

4.9 Speech and language impairments

Accessibility issues for users with speech impairments generally relate to the production of spoken language. Impairments such as stutters, apraxia of speech (i.e. following a stroke), or using voice prosthesis following a laryngectomy affect how the user produces speech, but do not affect understanding. However, users experiencing aphasia, i.e. after a brain injury or stroke, may find both their comprehension and their production of language is affected [40].

The key accessibility consideration in CUIs for speech and language impairments is adaptability to work through text or audio, or a user-defined combination of both. A person with aphasia may need to receive information in both audio and text (i.e. audio with text captions) but may need to respond using voice [40]. A person with apraxia may prefer to type their input but this should not mean they are restricted to text-only interaction from the CUI [40]. A person with a stutter may find their input method changes according to their circumstances, or how their stutter is on the day). Flexibility and user agency is key for this group.

4.10 Dyslexia and specific learning difficulties

The most common specific learning difficulties include dyslexia, dyscalculia, dysgraphia, dyspraxia and attention deficit-hyperactivity disorder (ADHD). De Santana gives a detailed overview of accessibility considerations for dyslexic users [54]; of these, the key considerations for CUIs are to ensure consistent navigation; avoid italics, block capitals, underlining, serif fonts, justified alignment, animation and small sizes in text formatting; ensuring the language is clear and concise; offer voice and/or text interaction and support customization of colour settings [54]. Dyscalculia and dysgraphia affect mathematical ability and handwriting, and do not appear to require specific accessibility considerations for CUIs beyond general good practice. Dyspraxia affects movement and hand-eye coordination, so CUIs should be keyboard accessible, with visual focus and adequately sized buttons, as per WCAG guidance [31]. For users with ADHD, recommendations suggest a ‘distraction free layout’, ‘clear instructions and error handling’, ‘avoiding time limitations’ and ‘avoiding animated content’ [55], as per WCAG [31].

4.11 Applicability of Universal Design principles

A final area to consider is the applicability of overarching design principles; namely those of Universal Design. Universal Design was originally conceived as a framework to support the design process towards the following goal: ‘The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design."[56]. It is based on seven principles, which provide a broad framework for accessible and inclusive design in a variety of contexts:

- Equitable Use
- Flexibility in Use
- Simple and Intuitive
- Perceptible Information
- Tolerance for Error
- Low Physical Effort
- Size and Space for Approach and Use

These principles can be applied in a variety of ways, and when taken into consideration with WCAG guidance and disability-specific needs, they begin to present a holistic picture of design considerations.

5 Issues for consideration in designing CUIs to be accessible

At this stage, the limited research and development around accessible CUIs means raises questions that needs exploration, rather than providing conclusive directives to achieve accessibility. Table 2 summarises the key issues raised above as questions for consideration in CUI design. As these are often related to more than one area of guidance discussed above, the relevant findings are noted

Table 2: Accessibility issues for consideration in designing CUIs

Consideration	**Related findings**
How is the sequence of the conversation meaningfully represented to users?	4.1, 4.11
How is the purpose of a users’ input at the current time represented to them?	4.1
How does the CUI and the channel it is delivered through combine to be operable by all users?	4.1, 4.11
How can the keyboard focus be made relevant to the conversational flow?	4.1
How is a conversation navigable (e.g. the history and direction of it)?	4.1
How can the outcomes of actions be predictable to users?	4.1
What errors are likely to occur and how are they prevented or recovered from?	4.1, 4.11
How are standard approaches used to ensure compatibility with assistive technology?	4.1
How can the CUI be operated through visual elements and without audio?	4.2, 4.4, 4.8
How accessibility preferences of the user carried forward where the CUI integrates with or embeds other interfaces?	4.2
How is the accessibility of hybrid elements (e.g. GUIs embedded into chat) ensured?	4.3
Should the system offer in-built accessibility features that replicate those of the users' AT to them? (e.g. providing audio or reverting to user of a screen reader)	4.3
How are audio versions of text conversations provided?	4.3
Where can the CUI reduce / remove the need for physical interactions (e.g. replacing keyboard or mouse actions with voice)?	4.4, 4.8, 4.9, 4.10, 4.11
How does the CUI support flexibility, such as the option to switch between different input communication modalities to the user during the conversation?	4.4, 4.8, 4.9, 4.10, 4.11

How can the CUI avoid causing barriers for users who need more time to make responses?	4.4, 4.8
How can CUIs reduce or remove triggers of anxiety (e.g. excessive prompting or demands for input)?	4.5
How can the CUI and the channel it is presented in be designed to reduce cognitive load (e.g. be simple and uncluttered)?	4.5, 4.7, 4.11
How can communication be simplified?	4.6, 4.8, 4.11
Can the CUI offer a simplified and limited set of choices?	4.6, 4.8, 4.10, 4.11
How can unintended interactions be avoided?	4.6, 4.8
Can language use be constrained to avoid multiple potential meanings, or unclear language features such as figures of speech?	4.7, 4.11
How is the CUI transparent about its actions (e.g. when it will share personal data)?	4.7, 4.11

6 Discussion

Identifying and reviewing accessibility guidance in relation to CUIs has raised questions that should be considered in design, and that require further investigation through which effective designs can be developed. A larger question for debate is to what extent CUIs can be more accessible and useful to people with disabilities than other interfaces. The space of opportunities has yet to be mapped. To contribute to this and conclude, we introduce the rationale for our current work in this area. This provides a problem space in which we can employ the considerations raised, and an example of the potential opportunities for CUIs to support accessibility.

6.1 Applying a CUI to design for improving access and support: The ADMINS project

Prompted by our prior research that students disclosing disabilities experience difficulty with the forms and administrative procedures necessary to organize their study support [21], we are developing a CUI assistant to help students disclose disability information, and support a dialogue about their study needs, without the need to complete forms. The ‘Assistants to the Disclosure and Management of Information, Needs and Support’ (ADMINS) project, will initially develop and pilot this solution in our institution. However, we are working with other organisations to explore the adaptation of the created system to their contexts and user needs. The project explores how a CUI could overcome known challenges with forms, administrative processes, and supporting accessibility. These include that:

The person often has limited understanding of how to express their needs and conditions in ways that are understood by the organisation. A static form can only offer specific questions and limited guidance on how to complete these, while a CUI could explore areas with the student through multiple questions, and adapted language. It could be designed to capture detailed and accurate information through a dialogue.

The person may have limited knowledge of the support that could be available to them. Again, a form or web page can only offer static information. However, a CUI could identify an area where the student may lack understanding, at a relevant point in the conversation, and offer information and resources that are appropriate to them.

The person may require support in order to complete the processes that will provide them with support. In our institution, a discussion with a human advisor is an essential part of understanding the student and assessing the right support for them. However, most students complete an initial enrolment process online, and some students are not available or decline to take part in a subsequent discussion with advisors. An accessible CUI offers the potential to adapt to the user and reduce the barriers to communicating in these first interactions. In other scenarios beyond our institution, there may not be a human advisor who can provide one-to-one support around accessibility.

The person may need to communicate additional or changing needs, request guidance, and avoid repetition of information. The CUI can provide an interface to creating a profile that is updated and can be reused. The CUI can act as an assistant or agent to avoid undue burden and share relevant information.

As ADMINS is designed entirely for persons declaring disabilities, and with the intention to alleviate accessibility issues encountered in Web based forms, the CUI design will be under pressure to cater effectively for all user groups as outlined above. The considerations for design raised in table 2 provide a focus of our attention as we go through the process of designing, developing and testing the assistant. For example:

How can the CUI avoid causing barriers for users who need more time to make responses?
The assistant will not assume that a pause means that no response is going to be given. It will also need to save the state of the conversation, and design for returns to conversations if they are delayed in such a way that the user stops engaging or has lost track of what had occurred in the conversation. In testing, we will need to avoid a simplistic or sole focus on whether the assistant is ‘efficient’ in terms of quickly gathering information from users, to account for the potential that the ability to take more time is a positive feature of the design.

How is the CUI transparent about its actions (e.g. when it will share personal data)?

The assistant will be clear about its role as a mediator in a wider process of creating a profile and providing appropriate support. It will provide support for the user to understand how this process works as one aspect of helping the user to learn from the conversation. An important focus in the design is how summaries or clarifications of what the assistant has interpreted can be presented back to the user at appropriate points.

How can the outcomes of actions be predictable to users?

Unexpected outcomes could emerge from the system misinterpreting a statement made by a user. The potential causes of this and mitigation require attention throughout the process. One cause of poor interpretation could be due to the data used in designing and training the system. There is a need to represent the diversity of disabilities in the audience in order to avoid bias and represent the breadth of users. For example, interpreting the breadth of terms that might be used to describe a condition and using language that the user is comfortable with. Furthermore, user expectations of the actions and outcomes that are possible through the assistant need to be established. The CUI will make clear that it is not a human and has a particular purpose. For example, while the tone should be friendly, it should be clear that the aim is a useful conversation rather than 'chat'.

These and the other considerations drawn from this work help to prompt design for accessibility based on what can be drawn from existing literature. This approach will be expanded upon as we learn from experience with ADMINS, and will complement more direct approaches to testing of the accessibility of CUIs and the ADMINS assistant.

7 Conclusions

This paper has reviewed a range of current guidance, reports, research and literature on accessible design for different disability groups, including users with mental health issues, autism, health conditions, cognitive disabilities, dyslexia or learning difficulties, and sensory, mobility or dexterity impairments. We have collated guidance relevant to the design of accessible CUIs and identified the key accessibility considerations to be taken when designing them. Given the early stage of research and development in accessible CUI, we raise these as questions for exploration. With further work, clearer methods to ensure accessibility in this space should emerge.

While some of the questions for consideration may be challenging to resolve, we should remain aware of the potential opportunities of CUIs as well. In this regard, we introduce the ADMINS project as an example where a CUI is being designed specifically to improve experiences for users with disabilities. Through this project we will continue to investigate the questions this paper has raised and continue to explore and share best practice for accessible and inclusive CUIs.

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REFERENCES

[1] Susan Moore. 2018 Gartner Says 25 Percent of Customer Service Operations Will Use Virtual Customer Assistants by 2020. Article on Gartner.com. Available online at https://www.gartner.com/en/newsroom/press-releases/2018-02-19-gartner-says-25-percent-of-customer-service-operations-will-use-virtual-customer-assistants-by-2020 (last accessed 4/12/2019)

[2] Voicebot.ai. 2019. Smart speaker consumer adoption report, 2019. Voicebot.ai. Available online at https://voicebot.ai/wp-content/uploads/2019/03/smart_speaker_consumer_adoption_report_2019.pdf (last accessed 19/12/2019)

[3] Voicebot.ai. 2019. In-car voice assistant consumer adoption report, January 2019. Voicebot.ai. Available online at https://voicebot.ai/wp-content/uploads/2019/01/in-car_voice_assistant_consumer_adoption_report_2019_voicebot.pdf (last accessed 19/12/2019)

[4] Petter Bae Brandtzæg and Asbjørn Følstad. 2018. Chatbots: changing user needs and motivations. Interactions Vol. 25 Issue 5, September-October 2018, Pp: 38-43 DOI: 10.1145/3236669

[5] Bernhard Suhm, Josh Bers, Dan McCarthy, Barbara Freeman, David Getty, Katherine Godfrey, and Pat Peterson. 2002. A comparative study of speech in the call center: natural language call routing vs. touch-tone menus. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems, pp. 283-290. ACM, 2002.

[6] Ramin Yaghoubzadeh, Marcel Kramer, Karola Pitsch & Stefan Kopp. 2013. Virtual agents as daily assistants for elderly or cognitively impaired users. In International workshop on intelligent virtual agents, pp. 79-91. Springer, Berlin, Heidelberg.

[7] Ali Abdolrahmani, Ravi Kuber, and Stacy M. Branham. 2018. "Siri Talks at You": An Empirical Investigation of Voice-Activated Personal Assistant (VAPA) Usage by Individuals Who Are Blind. In Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 249-258. ACM, 2018.

[8] Shadi Abou-Zahra, Judy Brewer and Michael Cooper. 2017 Web Standards to Enable an Accessible and Inclusive Internet of Things (IoT) In Proceedings of the 14th Web for All Conference on The Future of Accessible Work, Article No. 9. Available online at https://dl.acm.org/citation.cfm?id=3058568#references (last accessed 4/12/2019)

[9] Michael McTear 2002. Spoken dialogue technology: enabling the conversational user interface. ACM Computing Surveys (CSUR), vol. 34 (1), pp.90-169

[10] Stefan Schaffer and Norbert Reithinger. 2019. Conversation is multimodal: thus conversational user interfaces should be as well. In Proceedings of the 1st International Conference on Conversational User Interfaces, p. 12. ACM, 2019.

[11] Stolfa, T., (2016) The Future of Conversational UI Belongs to Hybrid Interfaces, available from https://medium.com/the-layer/the-future-of-conversational-ui-belongs-to-hybrid-interfaces-8a228de0bdb5

[12] James Glass, Eugene Weinstein, Scott Cyphers, Joseph Polifroni, Grace Chung, and Mikio Nakano. 2005. A framework for developing conversational user interfaces. In Computer-Aided Design of User Interfaces IV, pp. 349-360. Springer, Dordrecht, 2005.

[13] Jennifer Hill, W. Randolph Ford & Ingrid G. Farrerasc. 2015. Real conversations with artificial intelligence: A comparison between human–human online conversations and human–chatbot conversations. Computers in Human Behavior, vol. 49, 245-250.

[14] Annabell Ho, Jeff Hancock, Adam S Miner. 2018. Psychological, Relational, and Emotional Effects of Self-Disclosure After Conversations With a Chatbot. Journal of Communication, Vol. 68 (4) pp. 712–733

[15] Iulian V. Serban, Chinnadhurai Sankar, Mathieu Germain, Saizheng Zhang, Zhouhan Lin, Sandeep Subramanian, Taesup Kim, Michael Pieper, Sarath Chandar, Nan Rosemary Ke, Sai Rajeshwar, Alexandre de Brebisson, Jose M. R. Sotelo, Dendi Suhubdy, Vincent Michalski, Alexandre Nguyen, Joelle Pineau and Yoshua Bengio. 2017. A deep reinforcement learning chatbot. arXiv preprint arXiv:1709.02349.

[16] Jutta Treviranus. 2019. The Value of Being Different. In Proceedings of the 16th web for all conference. ACM.

[17] Rafal Kocielnik, Saleema Amershi, & Paul N. Bennett. 2019. Will You Accept an Imperfect AI?: Exploring Designs for Adjusting End-user Expectations of AI Systems. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (p. 411). ACM.

[18] Samuel Holmes, Anne Moorhead, Raymond Bond, Huiru Zheng, Vivien Coates, and Michael McTear. 2019. Usability testing of a healthcare chatbot: Can we use

conventional methods to assess conversational user interfaces?. In Proceedings of the 31st European Conference on Cognitive Ergonomics, pp. 207-214. ACM, 2019.

[19] Armando Barreto and Scott Hollier. 2019 'Visual Disabilities'. In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[20] Lisa Seeman and Clayton Lewis. 2019 'Cognitive and Learning Disabilities' In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[21] Tim Coughlan and Kate Lister. 2018. The accessibility of administrative processes: Assessing the impacts on students in higher education. In Proceedings of the Internet of Accessible Things, p. 5. ACM, 2018.

[22] United Nations. 2006. Convention on the Rights of Persons with Disabilities and Optional Protocol. United Nations. Available online at https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf (last accessed 7/12/2019)

[23] Equality Act 2010. Guidance on matters to be taken into account in determining questions relating to the definition of disability. Government Equalities Office. Available online at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/570382/Equality_Act_2010-disability_definition.pdf (last accessed 7/12/2019)

[24] International Classification of Functioning, Disability, and Health: ICF. 2001. Geneva: World Health Organization.

[25] Higher Education Statistics Agency. 2018. Student 2017/18: Fields required from institutions in All fields: Disability. Higher Education Statistics Agency. Available online at https://www.hesa.ac.uk/collection/c17051/a/disable (last accessed 7/12/2019)

[26] Tom Babinszki, Anna Cavender, Michael Gower, Jeffery Hoehl, Darcy Lima, Erich Manser and Shari Trewin. 2019. Inclusive Writing. In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[27] Audrey Thurm, Cristan Farmer, Emma Salzman, Catherine Lord, and Somer Bishop. 2019. State of the Field: Differentiating Intellectual Disability From Autism Spectrum Disorder. Frontiers in psychiatry 10 (2019).

[28] Athanassios Protopapas and Rauno Parrila.2018. Is Dyslexia a Brain Disorder? Brain sciences 8, no. 4 (2018): 61.

[29] Laura O Wray, Shahrzad Mavandadi, Johanna R. Klaus, James D. Tew Jr, David W. Oslin, and Robert A. Sweet. 2012. The association between mental health and cognitive screening scores in older veterans. The American Journal of Geriatric Psychiatry 20, no. 3 (2012): 215-227.

[30] Öykü Mance Calisir, Eşref Cem Atbasoglu, Halise Devrimci Ozguven, and Şenay Olmez. 2018. Cognitive Features of High-Functioning Adults with Autism and Schizophrenia Spectrum Disorders. Turk Psikiyatri Dergisi 29, no. 1.

[31] Andrew Kirkpatrick, Joshue O Connor, Alastair Campbell, Michael Cooper (2018) 'Web content accessibility guidelines (WCAG) 2.1.' W3C Recommendation 5 June 2018. Available online at https://www.w3.org/TR/WCAG21/ (last accessed 4/12/2019)

[32] Raja Kushalnagar (2019) 'Deafness and Hearing Loss' In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[33] Shari Trewin (2019) 'Physical Disabilities' In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[34] David Swallow (2018) A web of anxiety: accessibility for people with anxiety and panic disorders [Part 1]. Blog post on The Paciello Group, Posted on Tuesday, 14 August 2018. Available online at https://developer.paciellogroup.com/blog/2018/08/a-web-of-anxiety-accessibility-for-people-with-anxiety-and-panic-disorders-part-1/ (last accessed 4/12/2019)

[35] David Swallow (2018) A web of anxiety: accessibility for people with anxiety and panic disorders [Part 2]. Blog post on The Paciello Group, Posted on Wednesday, 7 November 2018. Available online at https://developer.paciellogroup.com/blog/2018/11/a-web-of-anxiety-accessibility-for-people-with-anxiety-and-panic-disorders-part-2/ (last accessed 4/12/2019)

[36] Meinald Thielsch and Carolin Thielsch. 2018 Depressive symptoms and web user experience. PeerJ vol. 6 e4439. 28 Feb. 2018, doi:10.7717/peerj.4439

[37] Miriam Harris. 2017. How to design for people struggling with mental health. Digital Arts. Available online at https://www.digitalartsonline.co.uk/features/interactive-design/how-design-for-people-struggling-with-mental-health/ (last accessed 4/12/2019)

[38] Aditya Nrusimha Vaidyam, Hannah Wisniewski, John David Halamka, Matcheri S. Kashavan, and John Blake Torous. 2019. Chatbots and conversational agents in mental health: a review of the psychiatric landscape. The Canadian Journal of Psychiatry 64, no. 7 (2019): 456-464.

[39] Raluca Budiu and Page Laubheimer. 2018 'Intelligent Assistants Have Poor Usability: A User Study of Alexa, Google Assistant, and Siri' Nielsen Norman Group. Available online at https://www.nngroup.com/articles/intelligent-assistant-usability/ (last accessed 4/12/2019)

[40] Abi Roper, Stephanie Wilson, Timothy Neate and Jane Marshall (2019) 'Speech and Language' In Yesilada and Harper (eds) Web Accessibility; A Foundation for Research. Washington, USA: Springer. Available online at https://link-springer-com.libezproxy.open.ac.uk/content/pdf/10.1007%2F978-1-4471-7440-0.pdf (last accessed 4/12/2019)

[41] Chris Atherton. 2018. Cognitive difficulties: an overlooked aspect of accessible design. Blog post on UX Collective, posted 25 April 2018. Available online at https://uxdesign.cc/in-cognitive-difficulty-15304d8b798d (last accessed 7/12/2019)

[42] Antonina Dattolo, Flaminia L. Luccio, and Elisa Pirone. 2016. Web accessibility recommendations for the design of tourism websites for people with autism spectrum disorders. International Journal on Advances in Life Sciences 8, no. 3-4 (2016): 297-308.

[43] Autism.org. 2019. Designing autism-friendly websites. Autism.org. Available online at https://www.autism.org.uk/professionals/others/website-design.aspx (last accessed 17/12/2019)

[44] Caroline E Robertson and Simon Baron-Cohen. 2017. Sensory perception in autism. Nature Reviews Neuroscience 18, no. 11 (2017): 671-684.

[45] Karwai Pun (2016) Dos and don'ts on designing for accessibility. Blog post on Gov.uk. Available online at https://accessibility.blog.gov.uk/2016/09/02/dos-and-donts-on-designing-for-accessibility/ (last accessed 17/12/2019)

[46] Anh Nguyen. 2006. Creating an Autism Friendly Environment. National Autistic Society.

[47] Elspeth Bradley and Phoebe Caldwell. 2013. Mental health and autism: Promoting autism favourable environments (PAVE). Journal on Developmental Disabilities 19, no. 1 (2013): 8.

[48] Mark Walker. 2017. How Artificial Intelligence is empowering people on the autism spectrum. Blog post on AbilityNet, 30 Oct 2017. Available online at https://abilitynet.org.uk/news-blogs/how-artificial-intelligence-empowering-people-autism-spectrum (last accessed 8/12/2019)

[49] Amanda J Ross, Marvin S. Medow, Peter C. Rowe, and Julian M. Stewart. 2013. What is brain fog? An evaluation of the symptom in postural tachycardia syndrome. Clinical autonomic research : official journal of the Clinical Autonomic Research Society vol. 23,6: 305-11. doi:10.1007/s10286-013-0212-z

[50] Howard M Kravitz and Robert S. Katz. 2015. Fibrofog and fibromyalgia: a narrative review and implications for clinical practice. Rheumatology International 35, no. 7 (2015): 1115-1125.

[51] Anthony James Ocon. 2013. Caught in the thickness of brain fog: exploring the cognitive symptoms of Chronic Fatigue Syndrome. Frontiers in physiology 4 (2013): 63.

[52] A Chan. 1999. Review of common management strategies for fatigue in multiple sclerosis. International Journal of MS Care, 1(2), pp.23-31.

[53] John Richardson. 2009. The academic attainment of students with disabilities in UK higher education. Studies in Higher Education, 34(2), pp.123-137.

[54] Vagner F. De Santana, Rosimeire de Oliveira, Leonelo Dell Anhol Almeida, and M. Cecilia Calani Baranauskas. 2012. Web accessibility and people with dyslexia: A survey on techniques and guidelines. In Proceedings of W4A 2012 - International Cross-Disciplinary Conference on Web Accessibility. DOI: 10.1145/2207016.2207047.

[55] Lilianna Williams, 2017. 5 ways to make your Website or App Accessible for people with ADHD. Blog post on Lilianna A11y, posted on 6 November 2017. Available online at https://lilianna11y.com/2017/11/06/5-ways-to-make-website-app-accessible-for-people-with-adhd/ (last accessed 8/12/2019)

[56] Ronald Mace, 1985. Universal design: Barrier free environments for everyone. Designers West 33, no. 1 (1985): 147-152.