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LONG PAPER

Accessibility to electronic communication for people with cognitive disabilities: a systematic search and review of empirical evidence

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Abstract The purpose of this study was to identify and synthesize measures for accessibility to electronic communication for people with cognitive disabilities by seeking answers to the following research questions: What measures to make electronic communication accessible to people with cognitive disabilities are evaluated and reported in the scientific literature? What documented effects do these measures have? Empirical studies describing and assessing cognitive accessibility measures were identified by searches of 13 databases. Data were extracted and methodological quality was assessed. Findings were analyzed and recommendations for practice and research were made. Twenty-nine articles with considerable variations in studied accessibility measures, diagnoses, methods, outcome measures, and quality were included. They address the use of Internet, e-mail, telephone, chat, television, multimedia interfaces, texts and pictures, operation of equipment, and entering of information. Although thin, the current evidence base indicates that the accessibility needs, requirements, and preferences of people with cognitive disabilities are diverse. This ought to be reflected in accessibility guidelines and standards. Studies to systematically develop and recommend effective accessibility measures are needed to address current knowledge gaps.

Keywords Accessibility · Cognitive disabilities · Communication · ICT · Usability

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1 Introduction

1.1 Background

The importance of accessibility to information and communication in enabling people with disabilities to fully enjoy all human rights and fundamental freedoms is acknowledged by the convention on the rights of persons with disabilities (CRPD). It requires States Parties to take appropriate measures to ensure to people with disabilities access, on an equal basis with others, to information and communications, including related technologies and systems open or provided to the public [1].

People with cognitive disabilities commonly face barriers to electronic communication, such as using the Web and mobile phones [2, 3]. Efforts to address these barriers were initiated and solutions proposed. For example, several guidelines and so-called standards were published to guide the development of information and communication technology (ICT)-based products and services to ensure that electronic communication is made accessible to people with cognitive disabilities. A review of 20 guidelines of web accessibility found four design recommendations that at least half of the studied guidelines supported [2]. The remaining 82 design recommendations were each supported by 1–7 guidelines only. The review noted that the guidelines share certain limitations, such as being based on personal opinions of few experts, lacking supporting references, and lacking indications as to whether a particular guideline represents a consensus of researchers or has been derived from a single, non-replicated study. Therefore, it proposes a “move from trial and error to consensus to evidence-based practice” [2, p. 211]. This text intends to contribute to such a shift by identifying scientifically evaluated accessibility measures for electronic communication for people with cognitive disabilities.

Accessibility has been defined in numerous ways. Considering its explicit mentioning of cognitive capabilities, the definition used in this work views accessibility as "the extent to which products, systems, services, environments, and facilities are able to be used by a population with the widest range of characteristics and capabilities (e.g., physical, cognitive, financial, social and cultural) to achieve a specified goal in a specified context" [4].

For the purpose of this paper, electronic communication refers to communication by means of ICT-based devices that support communication and has a user interface [5]. Examples of such devices include mobile and smart phones, tablet, laptop and desktop computers, and kiosks. The term "communication" is used for exchange of information between people (e.g., between a journalist and readers) and exchange of information between a user and a system (e.g., between a traveler and a ticketing kiosk). Traditional communication theories build on the model of transferring information between sender and receiver (e.g., [6]), while more recent communication theories view communication as something constructed by two or more people or actors (e.g., [7, 8]).

Cognitive disabilities include cognitive impairments, and difficulties in performing activities and participation due to such impairments. Health conditions and impairments which may result in cognitive disabilities include attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD), Alzheimer's disease, aphasia, Asperger's syndrome, autism, dementia, dyslexia, intellectual impairment, mental illness, psychological impairment. People with cognitive disabilities may experience difficulties in electronic communication due to reduced capacity in mental functions, such as orientation, attention, memory, abstraction, organization and planning, experience and management of time, problem solving, language, and calculation [9, 10].

The prevalence of cognitive disabilities is uncertain as different health conditions or impairments may be included, and the criteria may vary between countries. In the UK, about 3.7 % of the population reports severe difficulty with day-to-day activities due to their memory, concentration or learning capacities being affected [11]. Similar prevalence figures for severe or complete problems in remembering and concentrating have been reported from Fiji (3.5 %), India (3.7 %), Indonesia (2.9 %), Mongolia (4.0 %), and the Philippines (2.4 %) [12]. Regarding specific diagnoses, worldwide prevalence of ADHD is about 5–7 %, dementia about 5–7 %, and intellectual disability about 1 % [13–16]. Dyslexia impacts approximately 5–17 % of a population [17]. Not only people with diagnosed dyslexia find reading difficult. About one in five 15-year-olds in the OECD countries do not demonstrate reading skills that will enable them to participate effectively and productively in life [18].

To ensure that this relatively large group of people can participate in the society, the environment, including products and services for electronic communication, needs to be cognitively accessible. Guidelines do exist. However, they appear to lack consistency and their scientific grounding seems uncertain. To support the development of evidence-based standards and guide future work on cognitive accessibility to electronic communication, knowledge about scientifically evaluated solutions or measures is a prerequisite. However, a systematic overview of current solutions was not found in the published literature.

1.2 Aim, objectives, and research questions

The performed literature review aimed to summarize the current evidence base on measures for cognitive accessibility to electronic communication. Its objective was to identify and synthesize scientifically evaluated and reported measures for accessibility to electronic communication for people with cognitive disabilities. The following research questions were addressed:

- What measures to make electronic communication accessible to people with cognitive disabilities are evaluated and reported in the scientific literature?
- What documented effects do these measures have?

2 Methods

A study protocol, a data extraction form and a quality assessment form were developed to ensure a systematic search and review process.

2.1 Search strategy

Searches for empirical studies assessing cognitive accessibility measures were performed in 13 web-based databases, see Table 1. Three categories of search terms—Medium, Disability and Outcomes—were used in combination, i.e., one term from each of the three categories was required for a hit.

Medium atm, cash machine*,[1] communication system*, cellphone*, cloud*, computer*, digital*, electronic communication*, electronic device*, ict, information system*, information tech*, information and communication tech*, interface*, internet, ipad*, ipod*, laptop*, mediated com*,

[1] * = Any letter. For example: 'accessib*' includes both 'accessible' and 'accessibility'.

messaging, mms, mobile phon*, on-line*, pad*, palmtop*, pc, phone*, player*, portable*, reader*, smart card*, smartcard*, smartphone*, sms, social media*, social medium*, surfpad*, tele* (tele communication*, telecommunication*, tele inform*, teleinform*, telephone*, television*), tv, terminal*, text message*, texting, ticket machine*, ticket purchasing point*, vending machine*, video*, web*.

Disability attention deficit, adhd, alzheimer*, aphasia, asperger*, autism, cognitiv* disab*, cognitiv* impair*, communicat* problem*, dementia, development* delay*, difficult* reading, dyslexia, intellectual impair*, intellectual* disab*, language disorder*, language impairment*, learning disab*, learning disorder*, mental* disab*, mental* ill*, mental impair*, mental* retard*, neuropsychia* disab*, neuropsychia* disorder*, neuropsychia* impair*, psych* disab*, psych* impair*, read* difficult*, slow learner*, slow reader*.

Outcome accessib*, comprehen*, effectiv*, effic*, interaction, language*, learnab*, linguistic*, listen*, read*, understand*, usab*, user experience*, usefulness, user friendl*, user satisfaction.

Where possible, searches were limited to abstracts or narrowed using subject specific tools. In Compendex, IEEE Xplore, and Inspec, searches were performed using database-specific terms. In DiVA, searches were performed using two broad search categories, namely, human–computer interaction and interaction technology.[2]

A priori inclusion and exclusion criteria were established. Articles addressing a measure intended to improve access to electronic communication for people with a cognitive disability, reporting primary research and that were peer-reviewed and published 1995 or later were included. Single-case studies, expert opinions, and literature reviews were excluded. The reference lists of selected articles were reviewed for includable studies.

Search terms were identified and agreed by all authors while the searches were carried out by the first author. The total number of hits by database is indicated in Table 1.

The searches were run between February 18 and March 26, 2013 generating a total of 10,206 hits. Applying the inclusion and exclusion criteria, the first review of titles and abstracts resulted in 10,030 hits being excluded. From the remaining 176 hits, 21 duplicates were excluded. The second review of titles and abstracts resulted in the exclusion of 64 articles. Following the review of the full texts of the 91 remaining articles, another 66 articles were excluded, resulting in the selection of 25 articles. An additional 4 articles were included of which one was found in a database and three articles were found in reference lists of selected articles. This resulted in a total of 29 included articles. The search process is summarized in Fig. 1.

2.2 Quality assessment

Using an adapted version of a quality assessment tool developed by a health economist [19], the quality of the included articles was assessed in terms of their objective, background, design, methods, data, findings, and discussion, see Appendix. A maximum score of 2 could be awarded to each of 10 items, making the maximum possible total score 20. Quality rating A corresponds to a score of 17–20, B corresponds to a score of 11–16, and C corresponds to a score of 10 or less.

The first author assessed the quality of all included articles and the second author assessed five articles. Any

Table 1 Number of hits by database

Database	Hits
ACM digital library	0
AMED, CINAHL, and ERIC	1,367
BioMed central	219
Compendex	1,331
DiVA	438
IEEE Xplore	967
Inspec	873
PubMed	3,618
ScienceDirect	96
Scopus	341
Web of science	956
Total (13 databases)	10,206

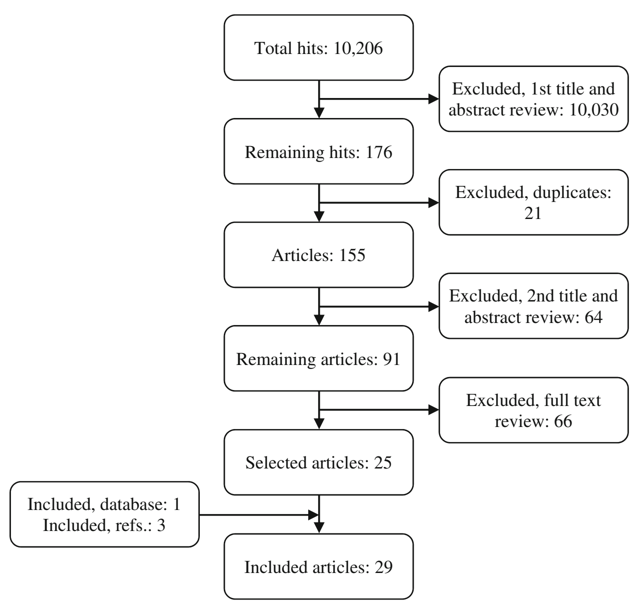

Fig. 1 Flow diagram of study selection

[2] Contact authors for a complete search history for each database.

differences in scoring were discussed by the two authors until consensus was reached. Where necessary, the quality assessments of the other articles were adjusted to reflect the agreed view.

2.3 Data extraction

To extract data from included articles, a form comprising the following data extraction categories was developed: Reference, Objective, Design, Method, Number of participants, Disability, Age and gender, Country, Environment, Medium or equipment, Type of communication, Outcome measures, and Results. Data were extracted by the first author. To further summarize the data, the categories were collapsed into broader areas.

Disability terminology evolves, which has resulted in certain terms used in the included articles being obsolete. In addition, preferred terms may vary between countries and disciplines. It is beyond the scope of this review to harmonize the diagnoses. However, the terms “mental retardation” and “developmental cognitive disability” have been replaced by “intellectual disability” except among the search terms and in Table 4, where the original terms remain in brackets.

2.4 Analysis and discussion

Extracted data were analyzed thematically according to type of electronic communication with a narrative summary of each included article. The findings are discussed and interpreted in Sect. 4, while implications for practice and research are discussed in Sect. 5.

3 Results

3.1 Description of included articles

Summaries of countries, reported diagnoses, and types of communication or interaction covered by the 29 included articles are given in Tables 2 and 3. It may be noted that 15 of the articles are based on studies in two countries (USA and UK) while the remaining 14 articles present studies from 11 different countries. The most common diagnoses in the articles were intellectual disability (eight articles) and dyslexia (six articles). The most common type of communication or interaction was Internet and reading texts on screen (five articles each).

Table 2 Countries represented in the articles

Countries	No. of articles
USA	9
UK	6
Spain	3
France	2
Belgium, Finland, Germany, Israel, Italy, Japan, Netherlands, Norway, Taiwan	1

A brief summary of each article is given in Table 4. Fourteen articles got quality rating A, 12 articles got B, and 3 articles got C.

3.2 Narrative synthesis

In this sub-section, a narrative synthesis of the reviewed articles is provided based on their type of communication or interaction. Accessibility measures and their outcomes among studied disability groups are described.

3.2.1 Internet

The use of web browsers and sites were studied in five articles. Compared with using Internet Explorer, users with intellectual disability performed statistically significantly better when they used a web browser that included audio prompting, reduced screen clutter, personalization and customization, graphics, consistent placement of buttons, and automating steps. Two types of audio prompting were used: (1) a message describing the use of a button was played when the cursor arrow was placed over it; (2) a message guiding the user to the next-most-likely step was played after a user-initiated event. A minimum of buttons and on screen features were displayed to minimize screen clutter [20]. In another comparison involving Internet Explorer, an adapted web browser increased reading comprehension among children with intellectual disability to a statistically significant degree. The adaptations included modification of the toolbar with functions used most frequently in Internet Explorer, voice description for toolbar functions, reading out of highlighted words or sentences by synthetic speech, and automatic pop-up of pictures corresponding to words or phrases when the user moves the mouse over them [21].

A comparison of a conventional website and an adapted version of it reported significant improvements in terms of usability and satisfaction among users with intellectual disability. The adapted website featured web pages that could be visualized in a full-screen format, elimination of the browser menu and controls, elimination of scrolling, back and home buttons inside the web pages, descriptive texts at the top of the pages, audio instructions, options represented by page-centered images distributed around a selection pictogram, and structured step-wise navigation [22]. In another comparison, this time between a standard website and a website developed for people with early-stage dementia, users with

Table 3 Reported diagnoses and types of communication or interaction

Reported diagnoses													
Types of communication or interaction	Intellectual disability	Dyslexia	Cognitive disability	Aphasia	Dementia	Acquired brain injury	ADHD	Autism	Depression	Schizophrenia	Learning disability	Other (cancer, physical and speech)	No. of articles
Internet	[20] [21] [22] [24]				[23]								5
Texts		[37] [38] [39] [40]					[36]						5
E-mail			[27]	[25]		[26] [28]							4
Multimedia interfaces		[42]						[43]	[45]	[45]	[44]	[45]	4
Telephone	[30] [31]		[27] [29]										4
Chat	[34]		[35]	[33]								[34]	3
Operating computer	[30] [48]		[47]		[47]								3
Entering information		[46]		[46]									1
Interactive TV					[32]								1
Pictures				[41]									1
No. of articles	8	6	4	4	3	2	1	1	1	1	1	2	

Table 4 Summary of extracted data from included articles and their quality rating

Reference and country	Design and participants	Types of communication	Intervention and main findings	Quality rating and strengths[a]
[20] USA	Quantitative controlled trial. 12 participants with intellectual disability (mental retardation), 20–45 years, 33 % females	Using Internet on computer	Compared with Internet Explorer, participants performed better ($p < 0.03$) in terms of independence, accuracy and task completion when using a web browser which utilizes multimedia	A. 1, 2, 3, 4, 6, 7, 8, 9
[21] Taiwan	Quantitative controlled trial. 10 participants with intellectual disability (mental retardation), grades 7–9, 30 % females	Reading web-based information on computer and interacting with browser interface	Compared with Internet Explorer, reading comprehension was higher ($p < 0.05$) when participants used an adaptive web browser with voice and picture assistance. The simplified interface was easy to learn	B. 1, 2, 4, 6, 8, 9
[22] Spain	Quantitative controlled trial. 20 participants with intellectual disability (mental retardation), 24–46 years, 40 % females	Interacting with website on computer	Participants tested a commercial website and an adapted version of it. Usability measures in terms of web understanding, number of visits, autonomy and success minus mistake trials were all higher ($p < 0.024$) for the adapted website. Satisfaction in terms of motivation and interest was higher ($p = 0.29$) for the adapted version. Correlation between web understanding and IQ was found for the commercial website ($p < 0.05$) while not for the adapted website ($p > 0.05$)	B. 2, 3, 4, 5, 6, 8, 9
[23] UK	Mixed methods trial. 5 participants with dementia, 57–72 years, 0 % females	Using Internet on computer	Participants were satisfied with both a standard format website and a website developed for people with early-stage dementia. Some specific areas were favored in both sites	A. 1, 2, 4, 6, 7, 8, 10
[24] USA	Mixed methods, cross-sectional. 27 participants with mild-to-moderate intellectual disability (developmental cognitive disability), 48 % or 52 % females	Interacting with website on computer	Being asked to carry out tasks on one of two different WCAG 1.0 compliant web sites, a majority of the participants were unable to successfully use them. The ability to navigate the web sites was impacted by unclear navigational confirmation, inconsistent navigation, non-standard interaction techniques, lack of perceived click-ability, user willingness to scroll pages, and user ability/willingness to read instructions	B. 1, 2, 6. 8
[25] Netherlands	Quantitative, cross-sectional. 26 participants with aphasia, 50–76 years, 38 % females	E-mail using computer	60 % of the participants found an assistive e-mail program for people with aphasia easy to use. 50 % use the program once or more a week. 40 % receive e-mails with attachments more than once a day. 20 % send mails with attachments. Almost all use the ready-made sentences/phrases provided with the program. 80 % compose new sentences	B. 1, 2, 6, 7, 8
[26] USA	Qualitative trial (participatory action research). 8 participants with acquired cognitive-linguistic impairment, 26–78 years, 50 % females	E-mail using computer	Participants reading and replied to e-mails across four writing prompts conditions (no prompt, Idea prompt, fill-in-the-blank, multiple choice). There was no clear preference for a particular prompt condition. E-mail partner preferences varied between the prompt conditions. Three categories of interface-related usability problems were identified: lack of knowledge about the functionality of keys for basic word processing operations; poor conceptual understanding for the mouse/cursor operation; and poor use of interface prompts. Four types of task- and message-related usability problems were identified: difficulty remembering the task; difficulty generating ideas for a message; lack of greeting and closure; and reduced error monitoring	A. 1, 2, 3, 4, 6, 7, 8, 10
[27] Italy	Quantitative trial. 13 Participants with cognitive disability	E-mail and telephone using computer	Participants were trained in using a multimodal communication application for e-mail and telephone. Among 21 set communication goals, 17 were reached or exceeded, 1 goal was not reached, and 3 goals were given up	C. 6, 8

Table 4 continued

Reference and country	Design and participants	Types of communication	Intervention and main findings	Quality rating and strengths[a]
[28] USA	Mixed methods, longitudinal. 4 participants with acquired brain injury, 37–65 years, 25 % female	E-mail using computer	Participants used an adapted e-mail interface and were followed for 9 months. All participants learned to become independent e-mailers. All participants reported increased feelings of social connectedness. Little to no change in cognitive processing was measured. Extensive training to learn keyboarding and editing was required. Occasionally, hands-on technical support was required. Each participant engaged in a unique set of e-mail topics	A. 1, 2, 3, 6, 7, 8, 10
[29] USA	Quantitative controlled trial. 16 participants with moderate to severe cognitive impairment, 28–81 years, 62 % females	Calling using mobile phone	Participants tested to call using three different mobile phone interfaces (standard, flip and picture modes) before and after being distracted. Before distraction: 100 % success for flip and picture mode, and 12.5 % success for standard mode. After distraction: 100 % success for flip mode, 81.3 % success for picture mode, and 6.3 % success for standard mode	A. 1, 2, 3, 4, 6, 7, 8
[30] USA	Quantitative controlled trial. 32 participants with intellectual disabilities, 18–54 years, 47 % females	Using a palmtop computer and its address book	Compared with using Windows CE operating system to navigate between and use functions, participants required less ($p < 0.001$) number of prompts, made less ($p < 0.001$) number of errors and identified more phone numbers when they used a specially designed palmtop computer interface	A. 1, 2, 3, 4, 6, 7, 8, 9
[31] USA	Quantitative controlled trial. 22 participants with intellectual disabilities, 18–49 years, 41 % females	Calling using mobile phone	Compared with using a standard mobile phone to attempt making and receiving phone calls, participants required fewer ($p = 0.001$) prompts and made fewer ($p < 0.001$) errors when using a specially designed multimedia software	A. 1, 2, 3, 4, 6, 7, 8, 9
[32] Spain	Mixed methods, cross-sectional. 21 participants with mild-to-moderate Alzheimer's disease	Responding to questions and follow instructions on TV	Using a remote control with Yes/No buttons, all participants were able to follow instructions and respond to Yes/No questions by an avatar on a TV. The time to respond increased during a session. No fear, misunderstanding or inconvenience in relation to the avatar was noticed. 80 % of the sample responded verbally to the avatar	B. 2, 3, 5, 6, 7, 8
[33] Japan	Quantitative controlled trial. 3 participants with aphasia, 51–71 years, 0 % females	Responding to questions in computer-based conversations	As compared with using video chat system and screen sharing, when participants used video chat system, screen sharing and conversation support tools (Yes–No, scale, choice, map, calendar, clock, number) the numbers of questions and questions per minute increased and the numbers of uncertain answers and repeated questions decreased. All participants used all conversation support tools. The Yes–No and choice tools were used most frequently	C. 3, 4, 6, 8
[34] Finland	Mixed methods trial. 9 participants of whom 8 had intellectual disability and 1 had physical and speech disability, 14–37 years, 0 % females	Chatting using symbols on computer	Participants found a picture-based communication interface fast, fun and not hard to use and would be happy to use it again. Experiences were mostly equal to or exceeded expectations. Among 8 participants, the median time to create a message ranged from 1 to 7 min and the median number of symbols ranged from 2 to 6	A. 1, 2, 3, 5, 6, 7, 8
[35] Spain	Qualitative, observational. 11 participants with cognitive impairments	Instant messaging on computer	Participants were able to communicate using a pictogram-enabled instant messaging service. They found it interesting and entertaining. Those presented with a post-office metaphor (message, envelop, postman) found it less frustrating to communicate. Elaborate messages negatively impacted on communication interactivity, causing frustration among recipients who got to wait longer	C.

Table 4 continued

Reference and country	Design and participants	Types of communication	Intervention and main findings	Quality rating and strengths[a]
[36] Israel	Quantitative controlled trial. 20 participants with ADHD and 20 without ADHD, 15–18 years, 72 % females	Reading on computer	Participants carried out a reading comprehension task with two texts each in four conditions: printed with regular space, printed with extra space, computer screen with regular space, and computer screen with extra space. Participants with ADHD scored lower on correct answers ($p < 0.007$) and higher on percentage of errors ($p > 0.007$) and reading duration ($p < 0.007$) (Bonferroni-corrected p-values). Participants from the ADHD group were classified as having poorer ($p < 0.009$) sustained attention. Participants with poor or medium level of sustained attention obtained the highest number of correct answers when texts were displayed on a computer screen with extra space. No significant effects of type of presentation or text's spacing on reading duration were found. There was no interaction between level of sustained attention, type of text presentation and text's spacing	A. 1, 2, 3, 4, 6, 7, 8, 9
[37] UK	Quantitative controlled trial. 6 participants with dyslexia, 14–16 years, 0 % females	Reading on computer	Compared with default MS Word settings, 5 out of 6 participants made fewer errors ($p = 0.32$) when using a word processing environment which allowed for personalized font, color and space settings. Performance between default MS Word settings and personalized settings improved ($p < 0.05$)	B. 2, 3, 4, 6, 8, 10
[38] UK	Qualitative, cross-sectional. Experiment 1: 12 participants with dyslexia, 18–30 years. Experiment 2: 7 participants with dyslexia, 14–30 years	Reading on computer	Manipulating the appearance of the word processing environment and text presented within it, all participants in experiment 1 found a color scheme which was subjectively superior for them to black text on white background with Times Roman 10 or 12 point text. Each participant had his/her own favourite color combination, although brown text on murky green background was liked by all even if no one felt it was best. Sans-serif Arial was rated the best typeface by almost all. Applying bold to a text had a negative effect for most participants. All seemed to think that increasing the spacing between characters, words and lines was beneficial. Experiment 2: Changing color scheme appeared to be most helpful. Developed schemes varied between participants. Larger text size than default was preferred. Some appreciated spacing between characters and words. Altering the column width worked well for those with fixation problems. Coloring reversal characters (e.g., b and d) greatly improved the display of the document for all but the participant with the least difficulties	B. 2, 6, 8
[39] Belgium	Qualitative trial. 32 participants with dyslexia, 18–37 years, 78 % females	Reading on computer	Following campus wide introduction of two different dyslexia software, 21 out of 32 participants continued using the software, mainly for text-to-speech assistance with reading	B. 2, 5, 6, 8
[40] UK	Mixed methods, cross-sectional. 455 Participants with dyslexia, post-secondary school age, 51 % females	Reading and writing on computer	91 % of participants who had been provided equipment for dyslexia were satisfied or very satisfied with the hardware and software they had received. 95 % used their hardware and 82 % used their software often or always. 84 % were positive about the ease of use of hardware and 75 % about the ease of use of software. Participants commented very positively about the effect of the equipment on their studies	B. 1, 2, 3, 5, 6, 7, 8

Table 4 continued

Reference and country	Design and participants	Types of communication	Intervention and main findings	Quality rating and strengths[a]
[41] USA	Quantitative controlled trial. 50 participants with aphasia, average age 60 years, 30 % females	Picture-based communication using computer	When participants tested web images and icons, the error rate of icons was higher in 13 out of 25 nouns. Images slightly outperformed icons although not significantly. Most of the time participants got a concept faster from an icon than from a web image (non-significant difference). Participants with high and medium cognitive levels were faster with images, while those with low cognitive level were faster with icons. Images and icons worked equally well for participants with high cognitive level, while for the others, icons did a better job (non-significant differences)	A. 1, 2, 3, 4, 5, 6, 7, 8
[42] UK	Quantitative controlled trial. 30 Participants with dyslexia, 18–36 years	Learning statistics from computer-based teaching materials	Participants using "text only" to learn statistics improved more ($p < 0.04$) than those who used "text and diagrams" or "sound and diagrams"	A. 2, 3, 4, 5, 6, 7, 8
[43] France	Quantitative controlled trial. 10 participants with autism, average age 13 years, 0 % females. 10 controls without autism, average age 9.5 years, 20 % females	Understanding facial expressions and finding errors in dialogs on computer	While controls performed higher ($p < 0.04$) with both a simple (text only) and a rich (text, synthetic voice, image) interface, participants with autism performed better ($p = 0.058$) with a simple interface but not with a rich interface. Controls performed better ($p < 0.05$) than participants with autism when facial expressions were used in dialogs. Participants with autism recognized both human and cartoon pictorial style facial expressions to similar degrees	A. 1, 2, 3, 4, 5, 6, 7, 8
[44] Germany	Quantitative controlled trial. Experiment 1: 20 participants with learning disabilities, 14–22 years, 45 % females. Experiment 2: 47 participants with learning disabilities, 14–21 years, 36 % females	Learning about computers and Internet (experiment 1), and the human body (experiment 2)	Participants tested one out of four different representational formats. None of the participants had specifically learnt with symbols before. Experiment 1: Results for both recognition and understanding were highest for text + spoken text + symbols, followed closely by text + spoken text. Results for text + symbols were lower and for text only lowest. Although not statistically significant, the mean scores for formats with spoken text resulted in higher scores than those without. No such difference was found between formats with and without symbols. Experiment 2: compared with text + spoken text + symbols, knowledge gain in verbal test were lower for text ($p > 0.1$), text + spoken text ($p < 0.05$) and text + symbols ($p < 0.01$). Compared with text + spoken text + symbols, knowledge gain in pictorial test was lower for text + symbols ($p > 0.05$), text + spoken text ($p < 0.05$) and text only ($p < 0.05$)	A. 1, 2, 3, 4, 6, 7, 8
[45] USA	Qualitative, focus groups and interviews. 21 participants of whom 5 had schizophrenia, 7 had cancer and 9 had depression	Providing information to potential research subjects using computer	Participants generally felt that a multimedia tool was useful and could replace a paper document for informed consent. It would be less stressful. They liked that information was provided in a hierarchic and modular approach, and felt that video use made information more understandable	B. 1, 2, 3, 6, 8
[46] Norway	Qualitative trial. 2 participants of whom 1 had aphasia and 1 had dyslexia, 0 % females	Entering information in mobile terminal	Participants could employ a speech-centric multimodal interface to use a map-based information service, while they could neither use text only nor speech only	B. 4, 6, 8

Table 4 continued

Reference and country	Design and participants	Types of communication	Intervention and main findings	Quality rating and strengths[a]
[47] France	Quantitative controlled trial. 15 participants of whom 4 had mild cognitive impairment, 7 had Alzheimer's disease and 1 had dementia, 65–89 years, 53 % females	Mouse interaction with computer	Participants selected a piece of sugar and put it in a cup of coffee with the help of a mouse with three different interaction techniques: clicking, dragging, and clicking and magnetization. Identified difficulties with mouse: keeping the mouse steady when moving; losing the cursor out of the exercise map; bad control in moving in the adequate direction; running out of the room on the mouse cursor; the mouse cursor getting stuck. Dragging was rejected by participants with cognitive impairments. Dragging takes longer time than clicking or clicking and magnetization. Clicking and magnetization generated short times also for those with low Mini Mental Score	B. 2, 6, 8
[48] UK	Quantitative trial. 5 participants with profound and multiple intellectual disability, 15–28 years, 40 % females	Activating video file on computer	2 out of 5 participants learnt to use functional action to trigger a video file by symbols on cards shown to cameras and recognized by open source software	A. 1, 2, 3, 5, 6, 7, 8, 10

[a] Quality assessment items in "Appendix" awarded a score of 2

dementia were satisfied with both sites but preferred different features of them. Although the length of the pages was not shorter on the new website, users experienced fewer scrolling problems on it, which is suggested to be explained by "cleaner" look of the pages and fewer choices. With changes to the contents menu, particularly with the addition of icons, there was a greater confusion between menu and text on the new site. There were more instances of clicking on non-linked items in the new site, mainly on explanatory bullet points [23].

In a study of two WCAG 1.0 compliant web sites, users with intellectual disability were unable to use both of them [24].

3.2.2 *E-mail*

Four articles address electronic communication via e-mail. An e-mail program with categorized ready-made sentences or phrases and images that can be included in the mail was found to be easy to use by 60 % of study participants with aphasia while the remaining participants found the program reasonably simple or complex to use [25]. In a comparison of four prompt conditions to write e-mails, the participants with cognitive impairments did not express any clear preference for writing on a blank e-mail screen, writing on a blank e-mail screen below a list of e-mail composition ideas, filling in the blanks in an e-mail template by writing, or filling in the blanks in an e-mail template by choosing words from pull-down menus with five set options [26]. In addition to composing mails using texts and icons, one e-mail program allowed recorded speech and the use of customizable keyboards. Although most of the 21 users with cognitive disabilities appeared to have achieved or exceeded their goals in using this program, explicit outcomes of it were not reported [27].

In a longitudinal study of a specialized e-mail program, all four users with acquired brain injury endorsed the social benefits of e-mail and achieved successful outcomes for several of their individual goals, including learning a new skill, and feeling connected with friends and family. Features of the e-mail program include that the user cannot exit it, the e-mail partners are fixed and can only be changed by care providers, and the most recently received message from a partner is shown in the top window while the bottom window is used to compose a reply. To overcome problems related to e-mail addresses, a visual address book was implemented [28]. A visual address book was also tested in another e-mail program [27].

3.2.3 *Telephone*

Four articles report on studies of telephone functions. Three of them compare specially designed interfaces with standard interfaces, concluding that the former are more effective than the latter. First, three modes of mobile phone operation were tested by participants with moderate to severe cognitive impairment before and after being distracted. Participants were completely successful when they simply had to open the mobile phone (flip mode). When they had to open the mobile phone and touch the correct picture (picture mode), the participants were completely successful before distraction and slightly less successful after distraction. Finally, when they had to dial a 10-digit number and press the send button (standard mode), the success rate was low [29]. Second, in a comparison of Windows CE and a specially designed palmtop computer interface (see description in Sect. 3.2.8), participants with intellectual disabilities were able to correctly identify more phone numbers when they used an interface with pictures [30]. Third, in a comparison of a standard mobile phone and a specially designed interface, participants with intellectual disabilities were more successful in making and receiving phone calls when they used the special interface with, e.g., pictures, audio prompts, and fewer buttons [31].

In a non-controlled trial of a multimodal communication application, participants with cognitive disability also used a visual phonebook. A click on the photo of a person allowed the participants to choose between phone call and e-mail/SMS composition. Phone book scrolling could be manual or automatic. Although no explicit outcomes of using the telephone function are reported, most participants seem to have reached or exceeded their goals [27].

3.2.4 Interactive TV

Addressing interactive TV, one article reports that users with mild-to-moderate Alzheimer's disease were able to follow instructions and respond to Yes/No questions by an avatar on a TV. Responses were made with a remote control. The avatar had a realistic voice and its lip movements were synchronized with its speech [32].

3.2.5 Chat

Three articles on chatting were identified. One controlled trial presents a video chat system with screen sharing complemented with conversation support tools [33]. The conversation support tools increased chat performance of users with aphasia and included:

- Yes–No tool: Window containing "Yes", "No" and "Not understood" buttons.
- Scale tool: A scale bar is shown.
- Choice tool: Text areas for a conversation partner to type in.
- Map tool: Web-based map system.
- Calendar tool: A blank calendar.
- Clock tool: Clock without hands.
- Number tool: A group of numbers.

Two studies explored picture-based communication interfaces, which were found to be fast, fun, not hard to use, interesting, and entertaining. In the first study, participants—mainly with intellectual disabilities—tested a user interface which was organized into three main sections: (1) message history and chat partners, (2) symbol input view, and (3) symbol category view. The application supported various input and output modalities. It was designed for graphical symbols, speech output, and touch-screen input. Text output, mouse interaction, and keyboard input could also be used [34]. In the second study, participants with cognitive impairments were able to communicate using an interface that was divided into a login window, a contacts window, and a dialog window. Written language was replaced by pictograms, including passwords. The dialog window was made up of five sections: (1) pictogram categories, (2) most frequent pictograms in a conversation, (3) pictograms of selected category, (4) actual conversation, and (5) pictogram input space [35].

3.2.6 Texts

Five articles reported studies of reading on screens. Noting that participants with ADHD had poorer sustained attention, a controlled trial found that those with poor or medium level of sustained attention obtained the highest number of correct answers in a reading comprehension task when texts were displayed with extra space on a computer screen (see Table 4 for details) [36]. Another controlled trial found that participants with dyslexia made fewer reading errors when they could use personally preferred settings in terms of font, color, and space as compared with MS Word standard settings [37]. This confirms previously published findings of another word processing environment experiment. By altering font, color, and space settings, participants with dyslexia were able to find preferred non-standard settings (see Table 4 for details). Brown text on murky green background was liked by all even if no one felt it was best. Almost all rated sans-serif Arial as the best typeface [38].

Two studies indicated that software and hardware for people with dyslexia were continuously used by a majority of those who had received them and that they were largely satisfied with equipment [39, 40].

3.2.7 Pictures

Pictures were studied in one article. In a sample of people with aphasia, it was identified that images and icons worked equally well in terms of accuracy for participants with high cognitive level, while for participants with medium or low cognitive level, icons worked better. It was also found that participants with high or medium cognitive level were faster with images, while participants with low cognitive level were faster with icons [41].

3.2.8 Multimedia interfaces

Possible benefits of multimedia interfaces have been reported in four articles. In two controlled trials, participants with dyslexia and autism performed better when they used text only interfaces. Students with dyslexia using "text only" to learn statistics improved more than those that used "text and diagrams" or "sound and diagrams" [42], and children with autism performed poorer when they used richer multimedia interfaces (text, speech, and images) while their performance improved when they used a simple interface (text only) [43]. Contrary findings have been reported among participants with learning disabilities. Also in a controlled trial, interfaces with text, spoken text, and symbols resulted in better recognition, understanding and knowledge gain than interfaces with text and spoken text, text and symbols, or text only [44].

In a study in which about two-third of the participants had depression or schizophrenia, a multimedia presentation of information with video was found to improve understandability of informed consent content. Using the system would be less stressful as it gave the participants a greater sense of control [45].

3.2.9 Entering information

One article explores a multimodal interface for small mobile terminals, which converts a web service to a map-based service supporting speech, graphic/text, and pointing modalities as inputs. Two participants with dyslexia and aphasia, respectively, could use the service by pointing at a map while uttering simple commands. They could use it neither by speaking and taking notes in the telephone-based service, nor by writing names in the text-based web service [46].

3.2.10 Operating equipment

Operation of equipment was studied in three articles. In comparison with Windows CE operating system for palmtop computers, participants with intellectual disabilities required statistically significantly fewer numbers of prompts and made statistically significantly less number of errors when they used a specially designed palmtop computer interface. The physical buttons on the front of the unit redirected to the new system when pressed, and access to the controls on the Windows Start bar and at the bottom of the display were removed. The new system provided a capability to create customized, oversized multimedia buttons to launch applications and features. Clicking once on a button on the main display generated an audible message identifying the purpose of the button and cuing the user as how to proceed. Tapping a button twice would start an application [30].

Three ways of interacting with a mouse were tested by people with various cognitive disabilities. The "dragging" technique was rejected by the study participants and required more time than "clicking" and "clicking and magnetization" (see Table 4 for further details). Dragging corresponds to the usual drag and drop by maintaining pressure while moving an item on the screen. Clicking corresponds to clicking both at selecting and deselecting an item on the screen item. Finally, clicking and magnetization corresponds to selecting an item by clicking it. It will then follow the cursor until it is moved to a place on the screen where it is deselected automatically [47].

In a study of activating video files by symbols on cards shown to cameras and recognized by open-source software, two of five participants with profound and multiple intellectual disabilities learnt to activate the video file [48].

4 Discussion

This section discusses characteristics of the included articles, their findings, and methodological aspects of this review. Implications for practice and future research are also considered.

4.1 Studies

Slightly more than half of the articles (15 out of 29) reported studies that were carried out in two countries only. According to cognitive theories, social factors may be of relevance to the design of accessible interfaces for electronic communication for people with cognitive disabilities [49]. Therefore, studies from a wider range of countries or cultures would be required before global accessibility recommendations are made.

Nearly half of the articles (14 out of 29) were limited to two different diagnoses. Each combination of reported diagnoses and types of communication or interaction in Table 3 was covered by very few studies, if any. Considering the role electronic communication plays in contemporary society, this raises a general concern about the attention the scientific community has paid to accessibility to electronic communication for people with cognitive disabilities. This situation calls for initiatives that explore accessibility measures for this group in various settings, as appropriate means, modes and formats of communication may vary across diagnoses and social contexts.

Almost half of the reported studies (14 out of 29) had a controlled design, either self-controlled or with a control group. None of the studies reported a power calculation, making it difficult to determine whether the sample sizes were appropriate for the stated purposes. In fact, several studies used small samples. This was reflected in the quality ratings, in which nearly half of the articles (14 out of 29) got the highest rating while 4 articles got the lowest rating. Some articles tended to describe the technical solutions well while other articles described the participants well. A sound discussion of the methodological limitations and their implications were missing in several articles.

The variation in quality rating is partly explained due to differences in type of publication and related limitations in space and differences in type of studies, e.g., pilot studies may be less detailed and not allow for statistical inference.

4.2 Study findings

Three controlled studies explored accessibility to Internet browsers and web sites. They present a range of features that reportedly improve the accessibility for users with intellectual disability. Two studies addressed accessibility to web sites. One of them noted that conformance with the accessibility standard web content accessibility guidelines (WCAG) 1.0 did not result in users being able to use such web sites. This may not be unexpected as elements relating to cognitive disabilities have been assigned lower priorities in the WCAG 1.0 [2]. There are concerns that this priority setting largely remains in the updated WCAG 2.0 [50]. In fact, the WCAG 2.0 acknowledges that "content that conforms at the highest level… will not be accessible to individuals with all types, degrees, or combinations of disability, particularly in the cognitive language and learning areas" [51].

Little evidence is available on what measures make e-mail accessible. None of the included articles used a controlled design. However, there are indications that ready-made sentences or phrases facilitate communication of people with aphasia. Moreover, it appears that users with acquired brain injury benefit socially from using a simplified e-mail program.

The use of pictures for making and receiving phone calls is supported by three controlled and one non-controlled trials. Although contemporary mobile phones and smartphones may not have incorporated all studied accessibility features, such as audio prompting and reduced numbers of buttons, most of them allow for pictures of contacts.

Chatting is a form of electronic communication that may or may not allow users to see each other during a conversation. In a controlled trial, ready-made tools for responding were found to improve video chatting performance by people with aphasia. Among other user groups, two studies support the use of symbols and pictograms for chatting.

Reading texts on screens is a common feature of electronic communication. One qualitative and two controlled trials found that performance of users with ADHD and dyslexia improved when texts were displayed with extra space. In addition, users with dyslexia also benefitted from personally preferred fonts and colors. For example, all participants in one study preferred brown text on murky green background over black text on white background. This contradicts sweeping guidelines, such as: "Contrast ratio should be maximized when selecting colors for background and foreground elements" [5]. Rather, evidence indicates that measures to allow for individually selected background and foreground colors should be recommended in order to accommodate the needs of those who require high contrast, e.g., people with visual impairments, as well as the needs of those who benefit from color combinations with lower contrasts.

The importance of allowing for individually preferred settings is underscored by findings from three controlled trials related to multimedia interfaces. Users with dyslexia or autism performed better when they used simpler interfaces while users with learning disabilities performed better with richer multimedia interfaces. As cited by existing web design guidelines for users with cognitive disabilities, the top design recommendation was to use pictures, icons, and symbols along with text [2]. Considering the evidence, it may be better to recommend that the user should be able to set his or her preferred combination of such features.

Although supported by only one controlled trial, the performance of users of varying cognitive levels in using icons and images stresses the importance of allowing for individual preferences.

The identified articles provide little guidance on how to enter information into a system, although a limited test of an innovative multimodal system was reported. Another innovative interface used an avatar on a TV set in combination with a simple remote control, which reportedly worked well for the study participants.

Operating hardware constitutes an important part of electronic communication. One controlled trial indicated that palmtop computer interfaces may be designed in ways that improve performance. Another controlled trial found that drag and drop as a way to interact with a mouse was inefficient for users with cognitive disabilities.

4.3 Methodological aspects

Potential limitations of a systematic search and review include possible gaps in the searching procedure. To minimize this, a relatively wide range of both specific and general search terms were combined and used in relevant engineering, education, and healthcare databases available to the authors through the library services of two universities.

Not all articles reported diagnoses in a consistent manner, which made it impossible to categorize them properly. It is therefore likely that the diagnoses in Table 3 overlap each other. It would be beneficial if authors use established terminology for health conditions and impairments, e.g., diagnoses or functioning as found in ICF, ICD-10, or DSM-IV [9, 52, 53].

Similarly, the types of communication and interfaces used in Table 3 are based on categories emerging while analyzing the articles. In future work, developing a complete set of categories in advance will facilitate the identification of additional gaps.

For many years, the theoretical approach to communication has been the sender–receiver model. Lately, there has been a shift toward a more constructive approach. The latter leads to an increased demand on the user interface and the importance of its usability and use worthiness, which is of great importance when it comes to support civil rights, i.e., in the context of this article, enabling communication for people with cognitive disabilities.

The fact that about half of the included articles were based in two countries does not necessarily imply that more research in this area is being done there compared with other countries, Therefore, considering the limitation of restricting the review to peer-reviewed and scientifically published articles, our research group undertakes a similar review of gray literature.

Accessibility features of recent technologies and applications, such as tablet computers, smart phones, social networks, and alternative messaging platforms, were not well covered by the included articles. Similarly, possible advancements in terms of accessibility to electronic communication by international project, e.g., AEGIS and Cloud4All, were not considered [54, 55].

4.4 Implications for practice

The identified evidence base is rather thin and provides limited guidance for practice. However, it does indicate specific measures that may contribute to making Internet browsers, web sites, texts on screens, calling and certain hardware more accessible to certain groups of people with cognitive disabilities. The most important implication for practice, though, may be that the findings suggest that accessibility measures need to be adaptable at both group and individual levels.

Contrary to the intentions of existing accessibility guidelines, the findings indicate that guidelines conformance may sometimes sustain barriers and thus prevent certain groups from communicating electronically. It is therefore important that available evidence is considered when developing or revising guidelines and standards, such as the WCAG and its accommodation of the accessibility needs of people with intellectual disabilities.

4.5 Implications for future research

The findings warrant further research that contributes to creating a sound scientific basis for developing and implementing appropriate accessibility measures. This may include well-designed replications of some of the presented studies in order to verify or reject their findings. As resources are limited, coordinated efforts to identify, prioritise, and address knowledge gaps in terms of combinations of diagnosis groups and types of communication and interaction may be a cost-effective way forward. Compared with Table 3, the diagnosis as well as means, modes, and formats of communication and interfaces need to be expanded to ensure that all possible aspects are covered. Research priorities should be set in consultation with concerned user groups.

5 Conclusion

The findings of this review lead to the following conclusions:

1. The current evidence base on measures for cognitive accessibility to electronic communication is rather thin. Few studies, often with few participants, have researched few types of communication and interaction for a limited number of cognitive diagnoses, making it difficult to generalize most of the reported findings to larger populations.
2. The accessibility needs, requirements, and preferences of people with cognitive disabilities are diverse. Therefore, measures to ensure accessibility to electronic communication need to be individually adaptable. Guidelines and standards ought to reflect this in their recommendations.
3. There is a need for further research in this field, particularly as accessibility to information and communication is a key to people with cognitive disabilities being able to enjoy their human rights and fundamental freedoms.

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Appendix: Quality assessment tool

To each of the following 10 items, a maximum score of 2 points was awarded. 2 = Article complies completely. 1 = Article complies partly. 0 = Article does not comply at all.

1. Does the study have a clear and well-defined research problem?
2. Does the study justify the research problem?
3. Does the study clearly describe the methods used to address the research problem?
4. Does the study use an experimental design, including controls, to explore causality (maximum score 2)? Does the study use a correlation design to predict outcomes (maximum score 1)? Does the study use a descriptive design to describe and observe relations (maximum score 1)?
5. Are data clearly described with regards to source, collection method, sampling, sample size, time period and level?
6. Are primary data used in the main analyses?
7. Does the study answer all research questions?
8. Are all reported findings and results outcomes of the applied methods?
9. Does the study establish convincing causality between studied causes and effects?
10. Does the study critically discuss possible bias, robustness of the findings and limitations of the method?

References

1. UN: Convention on the Rights of Persons with Disabilities. Resolution 61/106. United Nations, New York (2007)
2. Friedman, M.G., Bryen, D.N.: Web accessibility design recommendations for people with cognitive disabilities. Technol. Disabil. **19**, 205–212 (2007)
3. Bryen, D.N., Carey, A., Friedman, M.: Cell phone use by adults with intellectual disabilities. Intellect. Dev. Disabil. **45**, 1–2 (2007)
4. Persson, H., Åhman, H., Arvei Yngling, A., Gulliksen, J.: Universal, inclusive, accessible, design for all; Different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects. Univ. Access. Inf. Soc. (2014). doi:10.1007/s10209-014-0358-z
5. SI, E.T.: Human Factors (HF); Guidelines for ICT Products and Services; "Design for All". European Telecommunications Standards Institute, Sophia Antipolis Cedex (2009)
6. Dimbleby, R., Burton, G.: More Than Words: An Introduction to Communication. Taylor and Francis, Oxon (1998)
7. Wertsch, J.V.: Voices of the Mind: A Sociocultural Approach to Mediated Action. Harvester Wheatsheaf, London (1991)
8. Clark, H.H.: Using Language. Cambridge University Press, Cambridge (1996)
9. WHO: International Classification of Functioning, Disability and Health (ICF). World Health Organization, Geneva (2002)
10. Scherer, M.J., Federici, S., Tiberio, L., Pigliautile, M., Corradi, F., Meloni, F.: ICF core set for matching older adults with dementia and technology. Ageing Int. **37**, 414–440 (2012)
11. ODI: Disability prevalence estimates 2010/11. Office for Disability Issues. http://odi.dwp.gov.uk/docs/res/factsheets/disability-prevalence.pdf (2012)
12. Mont, D.: Measuring Disability Prevalence. SP Discussion Paper No. 0706. World Bank, Washington (2007)
13. Willcutt, E.G.: The prevalence of DSM-IV attention-deficit/hyperactivity disorder: a meta analytic review. Neurotherapeutics **9**, 490–499 (2012)
14. Polanczyk, G., Silva de Lima, M., Horta, B.L., Biederman, J., Rohde, L.A.: The worldwide prevalence of ADHD: a systematic review and metaregression analysis. Am. J. Psychiatry **164**, 942–948 (2007)
15. Prince, M., Bryce, R., Albanese, E., Wimo, A., Ribeiro, W., Ferri, C.P.: The global prevalence of dementia: a systematic review and metaanalysis. Alzheimers Dement **9**(1), 63–75.e62 (2013)
16. Maulik, P.K., Mascarenhas, M.N., Mathers, C.D., Dua, T., Saxena, S.: Prevalence of intellectual disability: a meta-analysis of population based studies. Res. Dev. Disabil. **32**(2), 419–436 (2011)
17. McCandliss, B.D., Noble, K.G.: The development of reading impairment: a cognitive neuroscience model. Ment. Retard. Dev. Disabil. Res. Rev. **9**, 196–204 (2003)
18. CD, O.E.: PISA 2009 Results: Executive Summary. The Organisation for Economic Co-operation and Development, Paris (2010)
19. Ekman, B.: Community-based health insurance in low-income countries: a systematic review of the evidence. Health Policy Plan **19**, 249–270 (2004)
20. Davies, D.K., Stock, S.E., Wehmeyer, M.L.: Enhancing independent internet access for individuals with mental retardation through use of a specialized web browser: a pilot study. Educ. Train Ment. Retard. Dev. Disabil. **36**, 107–113 (2001)
21. Chu, C.N., Chen, M.C., Li, T.Y.: A study on the design and evaluation of an adaptive web browser for students with reading difficulties. In: ICCE'02 Proceedings of the International Conference on Computers in Education. ACM, pp. 1234–1235 (2002)
22. Sevilla, J., Herrera, G., Martinez, B., Alcantud, F.: Web accessibility for individuals with cognitive deficits: a comparative study between an existing commercial web and its cognitively accessible equivalent. ACM T Comput.–Hum. Int. 14(3) (2007). doi:10.1145/1279700.1279702
23. Freeman, E., Clare, L., Savitch, N., Royan, L., Litherland, R., Lindsay, M.: Improving website accessibility for people with early-stage dementia: a preliminary investigation. Aging Ment. Health **9**, 442–448 (2005)
24. Small, J., Schallau, P., Brown, K., Appleyard, R.: Web accessibility for people with cognitive disabilities. In: Conference on Human Factors in Computing Systems—Proceedings. Association for Computing Machinery, pp. 1793–1796 (2005). doi:10.1145/1056808.1057024
25. Mahmud, A.A., Martens, J.B.: Understanding email communication of persons with aphasia. In: CHI'11 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, pp. 1195–1200 (2011)

26. Sohlberg, M.M., Ehlhardt, L.A., Fickas, S., Sutcliffe, A.: A pilot study exploring electronic (or e-mail) mail in users with acquired cognitive-linguistic impairments. Brain Inj. **17**, 609–629 (2003)
27. Barbieri, T., Bianchi, A., Fraternali, P., Tacchella, C.: AutonoMamente project—design, implementation and evaluation of a multimodal domotic application to support persons with cognitive disabilities. In: 2010 12th IEEE International Conference on e-Health Networking, Applications and Services (Healthcom 2010). IEEE, pp. 324–331 (2010). doi:10.1109/health.2010.5556591
28. Sohlberg, M.M., Fickas, S., Ehlhardt, L.A., Todis, B.: The longitudinal effects of accessible email for individuals with severe cognitive impairments. Aphasiology **19**(7), 651–681 (2005)
29. Sesto, M.E., Nelson, R.K., Long, Y., Vanderheiden, G.C.: Evaluation of an experimental mainstream cellular phone feature to allow use by individuals with moderate to severe cognitive disabilities. Univ. Access Inf. Soc. **7**, 25–30 (2008). doi:10.1007/s10209-007-0099-3
30. Stock, S.E., Davies, D.K., Davies, K.R., Wehmeyer, M.L.: Evaluation of an application for making palmtop computers accessible to individuals with intellectual disabilities. J. Intellect. Dev. Disabil. **31**, 39–46 (2006)
31. Stock, S.E., Davies, D.K., Wehmeyer, M.L., Palmer, S.B.: Evaluation of cognitively accessible software to increase independent access to cellphone technology for people with intellectual disability. J. Intellect. Disabil. Res. **52**, 1155–1164 (2008)
32. Carrasco, E., Epelde, G., Moreno, A., Ortiz, A., Garcia, I., Buiza, C., Urdaneta, E., Etxaniz, A., Gonzalez, M.F., Arruti, A.: Natural interaction between avatars and persons with Alzheimer's disease. In: Computers Helping People with Special Needs. 11th International Conference, ICCHP 2008. Springer, pp. 38–45 (2008). doi:10.1007/978-3-540-70540-6_5
33. Kuwabara, K., Hayashi, S., Uesato, T., Umadome, K., Takenaka, K.: Remote conversation support for people with aphasia: some experiments and lessons learned. In: Universal Access in Human–Computer Interaction. Addressing Diversity. Proceedings 5th International Conference, UAHCI 2009. Springer, pp. 375–384 (2009). doi:10.1007/978-3-642-02707-9_43
34. Keskinen, T., Heimonen, T., Turunen, M., Rajaniemi, J.P., Kauppinen, S.: SymbolChat: a flexible picture-based communication platform for users with intellectual disabilities. Interact. Comput. **24**, 374–386 (2012). doi:10.1016/j.intcom.2012.06.003
35. Tuset, P., Barberan, P., Janer, L., Busca, E., Delgado, S., Vila, N.: Messenger visual: A pictogram-based IM service to improve communications among disabled people. In: NordiCHI 2010: Extending Boundaries. Proceedings of the 6th Nordic Conference on Human-Computer Interaction. Association for Computing Machinery, pp. 797–800 (2010). doi:10.1145/1868914.1869032
36. Stern, P., Shalev, L.: The role of sustained attention and display medium in reading comprehension among adolescents with ADHD and without it. Res. Dev. Disabil. **34**, 431–439 (2013). doi:10.1016/j.ridd.2012.08.021
37. Dickinson, A., Gregor, P., Newell, A.F.: Ongoing investigation of the ways in which some of the problems encountered by some dyslexics can be alleviated using computer techniques. In: ASSETS 2002. Proceedings of the Fifth International ACM SIGCAPH Conference on Assistive Technologies. ACM, pp. 97–103 (2002). doi:10.1145/638249.638268
38. Gregor, P., Newell, A.F.: An empirical investigation of ways in which some of the problems encountered by some dyslexics may be alleviated using computer techniques. In: ASSETS'00 Proceedings of the Fourth International ACM Conference on Assistive Technology. ACM (2000)
39. Diraa, N., Engelen, J., Ghesquiere, P., Neyens, K.: The use of ICT to support students with dyslexia. In: Holzinger, A., Miesenberger, K. (eds) Hci and Usability for E-Inclusion, Proceedings, vol. 5889. Lecture Notes in Computer Science, pp. 457–462 (2009)
40. Draffan, E.A., Evans, D.G., Blenkhorn, P.: Use of assistive technology by students with dyslexia in post-secondary education. Disabil. Rehabil. Assist. Technol. **2**, 105–116 (2007)
41. Ma, X., Boyd-Graber, J., Nikolova, S., Cook, P.R.: Speaking through pictures: images vs. icons. In: Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility. ACM, pp. 163–170 (2009)
42. Beacham, N.A., Alty, J.L.: An investigation into the effects that digital media can have on the learning outcomes of individuals who have dyslexia. Comput. Educ. **47**, 74–93 (2006)
43. Grynszpan, O., Martin, J.C., Nadel, J.: Multimedia interfaces for users with high functioning autism: an empirical investigation. Int. J. Hum. Comput. Stud. **66**(8), 628–639 (2008). doi:10.1016/j.ijhcs.2008.04.001
44. Zentel, P., Opfermann, M., Krewinkel, J.: Multimedia learning and the Internet: ensuring accessibility for people with learning disabilities. J. Assist. Technol. **1**, 22–32 (2007)
45. Jimison, H.B., Sher, P.P., Appleyard, R., LeVernois, Y.: The use of multimedia in the informed consent process. J. Am. Med. Inform. Assoc. **5**, 245–256 (1998)
46. Kvale, K., Warakagoda, N.: A speech centric mobile multimodal service useful for dyslectics and aphasics. In: 9th European Conference on Speech Communication and Technology. International Speech and Communication Association, pp. 461–464 (2005)
47. Vigouroux, N., Rumeau, P., Vella, F., Vellas, B.: Studying point-select-drag interaction techniques for older people with cognitive impairment. In: Universal Access in Human–Computer Interaction. Addressing Diversity. Proceedings 5th International Conference, UAHCI 2009. Springer, pp. 422–428 (2009). doi:10.1007/978-3-642-02707-9_48
48. Bunning, K., Kwiatkowska, G., Weldin, N.: People with profound and multiple intellectual disabilities using symbols to control a computer: exploration of user engagement and supporter facilitation. Assist. Technol. **24**, 259–270 (2012). doi:10.1080/10400435.2012.659832
49. Sharp, H., Rogers, Y., Preece, J.: Interaction Design: Beyond Human–Computer Interaction, 2nd edn. Wiley, West Sussex (2007)
50. Richardson, A.: Those WCAG forgot: designing for the cognitively disabled. Orange J. Tech. Commun. Inf. Des. **7**(2). http://orange.eserver.org/issues/7-2/richardson.html (2011). Accessed 18 Sept 2013
51. W3C: Web Content Accessibility Guidelines (WCAG) 2.0. http://www.w3.org/TR/WCAG20/ (2008). Accessed 18 Sept 2013
52. WHO: International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Vols. 1–3. World Health Organization, Geneva (1994)
53. APA: Quick Reference to the Diagnostic Criteria from DSM-IV-TR. American Psychiatric Association, Washington (2002)
54. AEGIS: About AEGIS. http://www.aegis-project.eu (2014). Accessed 14 Jan 2014
55. Cloud4all: What is Cloud4all? http://www.cloud4all.info (2014). Accessed 14 Jan 2014