Designing electronic graphic symbol-based AAC systems: A scoping review.

Part 2: Application of human-centred design

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Abstract

Purpose: This is the second of two papers summarising studies reporting on the design of electronic graphic symbol-based augmentative and alternative communication (AAC) systems. The aim of this paper was to describe the design approaches used, and to determine to what extent the principles of human-centred design (HCD) were reflected in the design approaches and processes used.

Methods: A scoping review was conducted. A multifaceted search resulted in the identification of 28 studies meeting the selection criteria. Data was extracted relating to four areas of interest, namely (1) the general characteristics of the studies, (2) features of the systems designed, (3) availability of the systems to the public, and (4) the design processes followed. In this paper, findings related to the last area are presented.

Results: Design approaches were often inconsistently described. User-centred design was mentioned more often than HCD. Even so, various HCD principles were considered in most studies. Notably, stakeholders were involved in the design process in all studies. However, users were not involved in all studies and stakeholder roles were predominantly informative rather than collaborative. Prototype and product evaluations focused mostly on usability rather than user experience. Although many design teams were multidisciplinary, engineers and computer scientists predominated.

Conclusions: There is a need for designers to be more transparent about the type of design approach used to guide the system design and also to clearly report on design approaches and processes used. The application of HCD to the design of graphic symbol-based AAC systems is still limited.

Keywords: assistive technology, augmentative and alternative communication, design process, electronic AAC systems, graphic symbols, human-centred design

Introduction

The design of assistive technology (AT) for the benefit of persons with disabilities is a complex task [1,2]. The involvement of the intended beneficiaries of the product in the design process is arguably even more important than when so-called mainstream products are designed, because designers often do not have disabilities themselves, and therefore cannot rely on their own experience of using or requiring the product they are designing [1]. At the same time, end user involvement is often complicated for a variety of reasons, including ethical concerns as well as communication and participation barriers that persons with disabilities face [3]. Human-centred design describes a range of design approaches where designers collaborate with potential users in order to ensure that the product or service designed is not only usable, but appropriate and acceptable to persons who may benefit from it [4].

This paper is the second of two describing the results of a scoping review of the literature that describes the design of electronic graphic symbol-based augmentative and alternative communication (GS-based AAC) systems. The first paper [5] provided general information about the studies and described the systems designed. It was found that most studies were done in high income countries, most authors were affiliated to fields of computer science informatics and engineering, and that most systems comprised of AAC applications that could be loaded onto a mobile hardware platform. Justifications for specific design decisions about vocabulary, symbols, layout and access options were somewhat limited. In this second paper, we review the design approaches and processes used in designing electronic GS-based AAC systems, and describe to what extent these approaches and processes align to the principles of HCD.

Electronic GS-based AAC systems have long been used in the field of AAC for the benefit of children and adults who have complex communication needs (CCN) [6–9]. Systems can range from devices that give access to as little as one message to complex systems where hundreds of graphic symbols are organised across various pages or screens, giving access to a large vocabulary. As described in the first paper, there is a substantial body of evidence attesting to improved communication skills resulting from the implementation of electronic GS-based AAC systems. At the same time, high rates of abandonment of AAC systems have been reported

[10], and system features and characteristics that negatively affect user experience have been identified as one cause [11,12]. While numerous technological advances and innovations associated with the mobile technology revolution have led to a proliferation of GS-based AAC systems [13], system designers may still face various challenges in the design process. The first paper illustrated how various features of the system need to be considered in the design process. However, these features do not only need to be considered, but need to be well-matched to the needs, preferences, and expectations of the end user and other stakeholders, as well as to the environments in which the systems are to be used. The well-known 'Matching Persons to Technology' (MPT) model and assessment process comprehensively stipulates all the areas and aspects that need to be considered in order to achieve a good match between the person and the assistive technology [14]. The lack of designers' exposure to the needs and capabilities of a specific population is a common challenge to designing effective and useful products for persons with CCN [15,16]. Consequently, there is often a mismatch between the AAC design features and the individual needs of the targeted population group [17]. A common critique of AAC system design and AT design is that manufacturers (or designers) design systems independent of the population for whom they are intended and that AAC innovations are technology driven [15,18,19].

Human-centred design (HCD) has influenced AT design practice since the 1990s and has shifted the focus from the user as the subject, previously addressed through a user-centred design (UCD) approach, to actively involving individuals within the design process [20,21]. The main premise of the HCD framework is that HCD practitioners [typically the technology/software developer and designer) learn from, and cooperate with, individuals and/or relevant stakeholders for whom the system or product is developed [4,16]. An HCD process typically includes various stages [22]. The first stage entails information gathering, in order for designers to understand and specify the context of use, the tasks to be completed, as well as the requirements of the target population. The next stage includes ideation and design which often includes producing and assessing design solutions through prototyping. The last stage is the evaluation of the product against the design requirements set out earlier in the process. Designers are often required to adjust or reiterate a design process to compensate for many challenges and tensions designers face when creating products, and thus the design process cannot be linear [4,23].

There are several approaches that fall under the overarching HCD framework, for example, ethnographic design, co-design, lead-user approach, and participatory design [4]. However, they all share the same set of design principles as set out below by the ISO 9241-210:2019 standard, as cited in Shekhovtsova et al. [24]:

(1) The design is based on a clear understanding of the individual, their tasks, and contexts.

(2) The user and other stakeholders are involved in the design and development process.

(3) The design is driven and defined based on the user group's feedback.

(4) The process is iterative.

(5) The user group's experience is addressed holistically within the design.

(6) The team is multidisciplinary, which will include various skills and perspectives.

These six principles overlap to some extent, and describe the type of information or input needed to inform the design process (Principle #1); the involvement of the users and other stakeholders in the process (Principles #2, #3 and #5), the iterative nature of the design process (Principle 4), and the design team composition (Principle #6) [24].

Engaging stakeholders within the design process requires much thought and preparation [1]. Designers ought to ask questions and determine how the stakeholders will be engaged and/or recruited, at which stage(s) they will be involved, what role they will play, and how they will be compensated for their time [1]. Depending on the specific HCD approach chosen, stakeholder engagement will take on different forms [21]. For example, participatory design promotes the active involvement of individuals throughout the design process and as such, stakeholders are treated as experts who play a role in the exploration and creation of alternative solutions for new products throughout the design process [4,25]. In contrast, an ethnographic design includes individuals as passive participators where the designer's goal is to better understand the target population's needs through observations of these individuals within naturally occurring activities [4].

This leads to the two different roles a stakeholder can play within the design process. In an informative role, a designer consults with stakeholders to gain more information regarding their needs, their tasks and their contexts, as well as to garner more information on the usefulness of a product. Alternatively, a stakeholder can be involved in a participative (collaborative) manner, whereby they are seen as co-creators and may influence decisions relating to the design of the intended product [26,27]. The latter is preferable but not always possible due to various limitations and constraints such as time, costs, ethical considerations, and the diversity and heterogeneity of people who use AT [28,29]. These factors may make it difficult to follow a single design approach, and designers are often somewhat eclectic [4].

The results of the scoping review reported in the first paper confirm the proliferation of the design of GS-based electronic AAC systems in the last few years. In light of the concerns raised regarding limited involvement of stakeholders in AT design in general and in the design of AAC systems in particular [15,30,31], this second paper explores the design approaches and processes used, and the extent to which these approaches and processes aligned with the principles of HCD.

Method

As reported in the first paper, a scoping review was conducted to identify and synthesise studies and reports on the design of electronic GS-based AAC systems. The broader descriptive questions about the nature of the design process and the extent to which it was aligned to HCD lent itself to a scoping review methodology [32]. The methodological framework developed by Arksey & O'Malley [33] and updated by Levac et al. [34] guided the review. The PRISMA extension for scoping reviews (PRISMA-ScR) [35] was also consulted. A review protocol was developed and revised by an academic with expertise in the field of AAC and assisitive technology.

Search strategy

As reported in the first paper, a multifaceted search strategy was developed by the authors in consultation with a subject librarian. A total of 24 electronic databases were searched on 4 November 2020, including databases that covered the fields of rehabilitation, education, linguistics, engineering, and computer science. The Boolean search string used (tailored to each database) was provided in Appendix A of the first article. A Really Simple Syndication (RSS) feed and search alerts were set up on all databases and monitored until January 2021. In addition, a search was conducted on Google Scholar. A hand search of the reference list of included articles was also conducted. More information on the search is provided in the first paper.

Selection of Studies

Studies were selected according to a list of inclusion and exclusion criteria, as reported in the first paper. Each record was independently screened by the first author and also either the second or third author. On title and abstract level, authors reached a 97.3% agreement an on full text level, they reached 83.4% agreement. Disagreements were resolved by consensus.

Data extraction

Data was extracted using a form developed on Microsoft Excel. The following data was extracted: (a) general characteristics of the studies, (b) description of the product/prototype that was designed, (c) design approaches used, and (d) HCD principles observed in the study. In this article, the results pertaining to (c) and (d) are reported. The second author extracted data from all the records. Data was then extracted independently for a second time by two trained research assistants, with each assistant extracting data from half of the identified records. Agreement on data extraction was 89%. Consensus was reached on most disagreements, with the first author acting as arbitrator in 0.5% of the disagreements. In preparation of this paper, the first author additionally extracted information pertaining to the HD principles. The second author independently extracted the same data and an agreement of 99,8% was found. Consensus was reached on disagreements.

Results

Search Results

The electronic database searches yielded 3628 records, and 97 additional records were identified via other sources (hand search and Google scholar search). A total of 3256 records remained after the removal of duplicates. A total of 3155 were excluded during title and abstract screening, leaving 101 records to be screened on full text level. A total of 73 were excluded on full text level, leaving 28 records to be included in the review. An overview of the studies was provided in the first article (Table 2).

Design approaches

A total of 18 studies specified the design approach used, while 10 studies did not explicitly specify this. Few studies (*n* = 5) mentioned an HCD approach. Martin et al. [36] discussed using HCD; however, did not specify which HCD approach they used to guide the design. The only HCD subtype that was reported was a participatory design approach – mentioned in four studies. However, each author reported a variation of the approach and/or used different terminology. Allen [37] reported on a "Designer-facilitated Participatory Design" (p.137); Boyd-Graber et al. [38] discussed using a modified version of a participatory design approach; and de Faria Borges [39] reported on an adapted "participatory design method for customised assistive technology (PD4CAT)" (p.1). Hayes et al. [40] used a mixed methodology and reported on both a participatory design approach and a UCD approach. HCD approaches like ethnographic design, contextual design, lead user approach, co-design, and empathetic design were not reported. A UCD approach was reported in nine additional studies, with one study specifically mentioning the UserFit methodology described as a specific form of UCD developed for AT. A total of four studies referred to other approaches or frameworks that guided the design of the system, including action research [41], an evidence-based practice approach [42], and exploratory design [43,44].

HCD Principle #1: Understanding of the human, task and context

The extent to which the target population, the task to be supported by the system, and the context in which it was to be used were described differed between studies. Regarding the target population, many studies (*n* = 16) mentioned that the AAC system was designed for persons with a specific diagnosis or diagnoses. These included autism spectrum disorders (*n* = 7), aphasia (*n* = 6), and cerebral palsy (*n* = 3). A total of eight studies did not mention specific diagnoses but described that the system was designed more generally for person with CCN, also described as "severe communication disorders" [45] or "speech and language impairments" [43, p.188]. In four studies, the populations were described in somewhat more detail by their functional and/or activity limitations, for example, "people who are illiterate and cannot speak" [37], "individuals with significant speech and motion impairment…neo-literates who have little proficiency in their language of communication" [45 p.173], and "people with severe speech and motor impairments" 46, p.279]. Hill [42] described the functional abilities of the "initial clinical population in feasibility testing" (p.257) in quite some detail, including sensory, cognitive, speech and language abilities and disabilities.

A total of 11 studies mentioned that the systems were designed specifically for children. Fewer AAC systems were designed specifically for adults (*n* = 4), while three studies reported designing a system for both children and adults. It is evident that many studies (*n* = 10) did not define the intended population age.

AAC systems were designed for persons from different language communities. English was reported most frequently as the language for communication (*n* = 7). Spanish (*n* = 3) and Portuguese (*n* = 3) were the next most common languages used by the target population. Japanese (*n* = 2), Chinese (*n* = 2), and Arabic (*n* = 2) were included within some of the studies as the language used for communication. Only one study each reported on Dutch (*n* = 1), Mandarin (*n* = 1), Hindi and Bengali (*n* = 1), and Croatian (*n* = 1) as languages used by the target population. Six studies did not specify the language of the target users. Only four studies made mention of cultural considerations in the design process, with two studies specifically referring to the need for culturally appropriate symbols [47,48].

Regarding tasks, most systems (*n* = 25) were aimed at improving the expressive communication of persons with CCN. Only two studies reported on systems designed to improve receptive communication [49,50]. In one study [49], a system was described that helped teachers compose pictographic sentences to facilitate comprehension of children with autism. Another study [50] described a system that enabled peers to produce picture-supported messages to communicate with children with CCN. One study did not specify the task [51]. All systems designed to support expressive communication tasks were designed to support synchronous, face-to-face interactions, although remote and asynchronous communication (e.g., via electronic chat functions or email) was also mentioned in two studies [45,49]. Some additional details about the communication tasks included specific communication functions and specific partners. Four studies reported on the design of systems to support specifically narration or storytelling, including fictional stories and the narration of personal experiences [36,45,52,53]. Daemen [52] mentioned designing a system for sharing basic needs and feelings. The communication partners with whom the person would engage with the help of the system were mentioned in four studies, and included persons in the school contexts [47], parents and teachers [49], peers [50], and “people in the vicinity” [46, p. 279].

In addition to improving expressive communication, the authors of three studies mentioned that the systems designed should also improve language skills of children with CCN [39,43,54]. Mendes and Correia [43] also mentioned that literacy skills should improve via the use of the system.

In 11 studies, authors mentioned that systems were intended for use in multiple contexts, in recognition of the fact that most users need to communicate with their system in multiple contexts within their day-to-day life. Authors of four studies discussed systems designed specifically on an educational environment. Authors of four other studies considered two environments such as home and classroom environments (*n* = 3), and home and rehabilitation centres (*n* = 1). In one study, authors reported designing a system for use outside of the home [38]. The authors of eight studies were not specific about the context in which the GS-based system would be used.

HCD Principles #2, #3 and #5: Stakeholder involvement

Stakeholders (including users) were involved in all the studies. In many studies (*n* = 20), designers consulted more than one group. For example, Babic et al. [51] involved the user, caregivers, educators and healthcare professionals within the design process. In 11 studies, only one stakeholder or one stakeholder group was involved. For example, Jafri et al. [55] only included the speech-language pathologist (SLP) as a stakeholder, whereas Karita [56]included teachers as a stakeholder group.

The individual (user) for whom the product was intended was involved in 19 studies. Other stakeholders involved in the design included health professionals (*n* = 19), parents/caregivers (*n* = 11), educators (*n* = 10), family members (*n* = 2), and one study included the users' peers within the design process [50]. Health professionals varied and included persons such as SLPs (*n* = 12), occupational therapists (*n* = 5) and psychologists (*n* = 6).

Stakeholder roles were classified as either informative or collaborative. In seven studies, both informative and collaborative stakeholder roles were reported (e.g., 38,39,53). Overall, the primary role of the stakeholders who were included within the design process was an informative one (*n* = 25). This means that they were consulted for information purposes only. In fewer studies (*n* = 12) were stakeholders actively involved in a collaborative role within the design process.

Stakeholders were involved in different stages of a design process. Most of the studies involved a different stakeholder group per stage. For example, Mahmud et al. [53] gained information from an experienced SLP and individuals with aphasia (user) in the initial stages and ideation (prototyping) stages but involved non-aphasic individuals to evaluate the final high fidelity prototype. Allen [37] consulted the same set of individuals throughout the design process, that is, adults with speech and language impairments (users). The stakeholders were commonly consulted within the initial, information gathering stages of the design process (n = 22), as well as during the final product testing stage (n = 22). In fewer studies (n = 17) were stakeholders involved during the ideation and design stage.

Information from users and stakeholders was gathered in a variety of ways (see Figure 1). Experimenting with prototypes and/or products was reported in 25 studies and was used to either gain user and/or stakeholder input during design and ideation or during the evaluation of the final prototype or product. The use of questionnaires and/or rating scales was reported in 14 studies – of these, 11 were custom-designed for the study. In three studies, previously published scales were used, namely the System Usability Scale [57], and the Software Usability Measurement Inventory [58] – both scales developed for general evaluations of systems and software rather than specifically of AT or AAC systems. Observations (n = 14) and interviews (n = 12) were also common methods used to gain user/stakeholder input. In six studies, focus groups were used to receive stakeholder input. Six studies discussed other methods such as a user acceptance test [46], consultations or meetings [38], and expert evaluations [41].

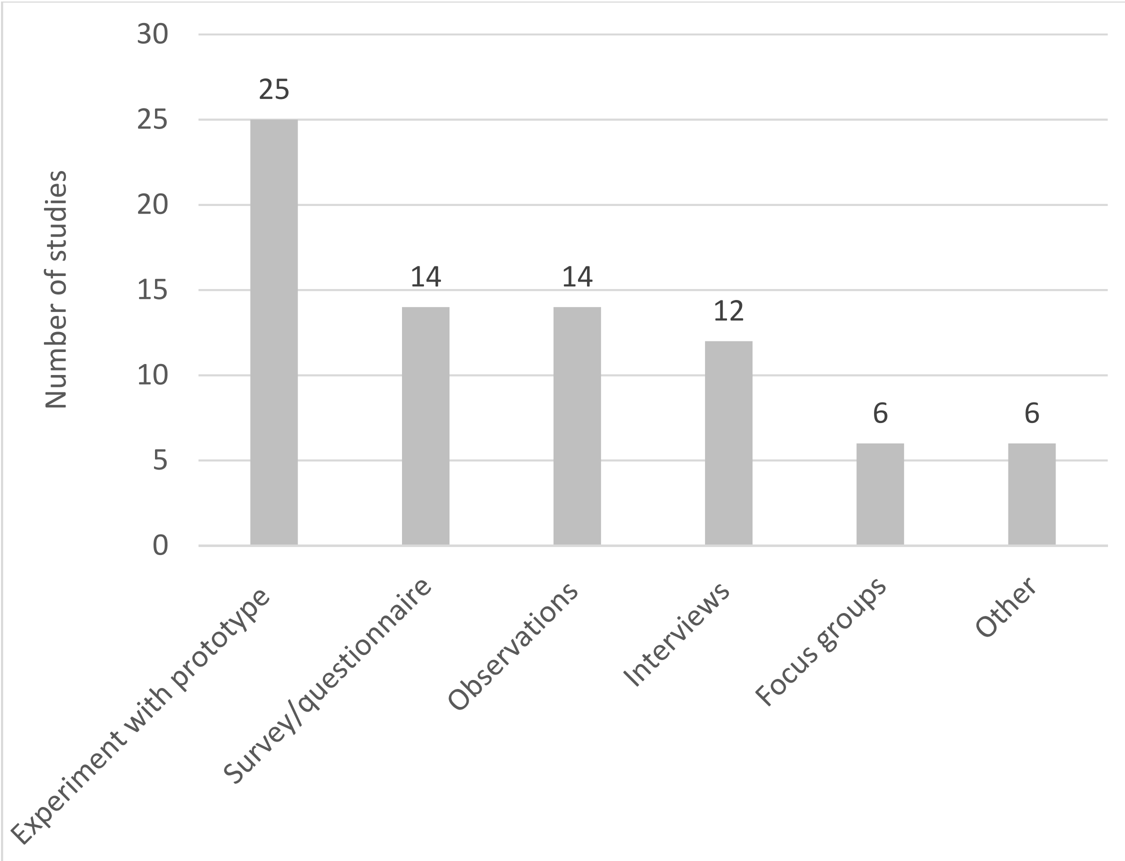

Figure 1. Number of studies reporting different methods of obtaining stakeholder information.

Only five studies mentioned making specific adaptations to circumvent communication challenges when obtaining input from persons with CCN. Allen [37] reported on the use of sketches and/or models to depict abstract design concepts to the intended users (adults with cerebral palsy, motor neuron disease or traumatic head injury) to improve their understanding and conceptualisation of the intended product. Da Silva et al. [59] mentioned making the System Usability Scale available on an app for easier access for adolescents and adults with cerebral palsy. Daemen et al. [52] described representing scale points on a Likert scale with smileys to facilitate comprehension by participants with aphasia. De Faria Borges et al. [39] engaged in collaborative drawing activities to elicit picture preferences of the 4-year-old child with cerebral palsy for whom their system was designed. Williams et al. [44] reported using aphasia-friendly communication techniques such as closed-ended questions, supportive conversations methods, pictures, and visual scales during interviews with persons with aphasia.

Regarding the content of user input, a total of 21 studies reported obtaining information from users and/or stakeholders about the user needs and/or design requirements for the envisaged system in the initial stage. Hill [42] reported more broadly exploring feasibility, acceptance, and perceived value of the proposed AAC solution during the planning stage. During the ideation and design stage as well as the final evaluation stage, the usability of the system was the construct most frequently evaluated by users and stakeholders. According to Tosi [22], usability is an overarching construct that encompasses aspects of efficiency, effectiveness, utility, ease of use and ease of learning. Usability in general and/or one of the aspects falling under usability was evaluated in 25 studies. Usability without further specification was mentioned in seven studies. More specific constructs mentioned included task performance (n = 9), ease of use (n = 9), use in real life (n = 6), and testing system functionality unrelated to a specific task (n = 3). Acceptance of the system and satisfaction, as two constructs related to user experience, were evaluated in six and four studies respectively. Lastly, quality of life was evaluated in two studies. Figure 2 gives an overview of the constructs evaluated in the ideation and design stage as well as the evaluation stage.

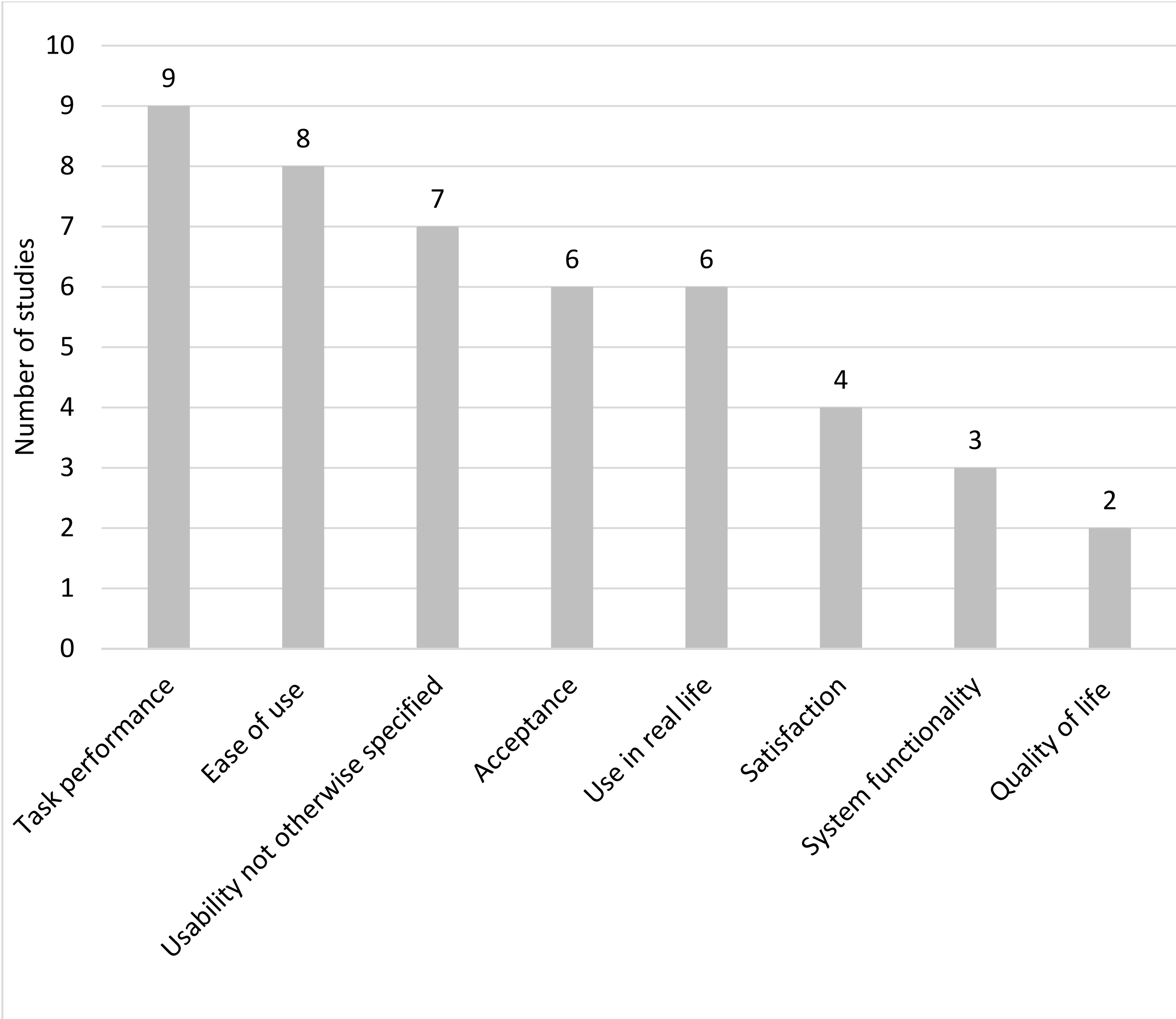

Figure 2. Constructs evaluated by stakeholders during the ideation and design stage as well as the product evaluation stage.

HCD Principle #4: Iterative nature of the design process

Iterative cycles of design and evaluation were mentioned in 14 studies. The number of iterations were specified in five studies [36,38,41,48,52], and ranged from two to four. In these studies, the prototypes developed with each iteration were described in detail, ranging from low fidelity paper-based prototypes to high fidelity functional electronic prototypes. In the other records, iterations were not enumerated, but more vaguely described, for example, as stages of design and evaluation that were "repeatedly performed" [39, p.8] or comprised of "several iterations" [51, p.7]. Fourteen studies did not describe iterations.

HCD Principle #6: Multidisciplinary team

Authors of the studies came from a variety of disciplines as evidenced by their institutional affiliations and/or their professional qualifications. In 17 studies, affiliations to departments/schools of computer science, informatics/bioinformatics, and engineering/bioengineering were mentioned. Interestingly, bioengineering and/or bioinformatics was only mentioned in three studies, while computer science and/or informatics was mentioned in 12 studies; engineering (including electrical and computer engineering) was mentioned in six studies, and a combination of engineering and computer science in two studies. Affiliations to health and rehabilitation departments or service delivery entities were mentioned in eight studies, while affiliations to technology (and/or AT) companies, development hubs or centres were mentioned in six studies. Affiliations to art and design disciplines were mentioned in five studies, as were affiliations to education and special education.

Additional designers and manufacturers were consulted in seven studies. Few studies reported consulting linguists (n = 3) and additional computer scientists (n = 2) during the design process. Other persons of various other designations were reported to be consulted in 10 studies, such as, typically developing individuals with no relation to the target population (e.g., non-aphasic adults or children without speech or language impairments at mainstream schools) (n = 2), visual designer or art illustrator (n = 2), assistive technology specialists (n = 1), software designer (n = 1), as well as engineers (n = 1).

Discussion

This paper aimed to (a) describe the design approaches that had been used in the design of electronic GS-based AAC systems, and (b) to describe the extent to which the approaches and processes used aligned to the principles of HCD. With respect to the first aim, there seemed to be limited consistency in the way authors described the design approach used. There were many authors that simply did not report the design approach that guided their decision-making and the processes used. This may be reflective of the strong orientation to design as praxis that still pervades the field of design [60]. Designers and developers may be practice-driven, and may therefore foreground the process of design and development without much consideration as to the underlying approach or theoretical orientation that drives their work [60,61] . Alternatively, the complexity of the design process (specifically the design of assistive communication technology) may defy a neat classification into one design approach, and designers may be using eclectic and customised processes and approaches that are hard to classify [4]. According to Redström [60], designers in the modern world are required to focus on complex phenomena such as interactions and social behaviours – fields that are traditionally studied using science, the scientific method and experimental design. However, designers often lack knowledge on these methods. It was interesting to note that one study used an evidence-based practice (EBP) framework – predictably, this study's author was an allied health professional. EBP presupposes the judicious use of scientific evidence (generated primarily by experimentally controlled studies) in clinical (and educational) practice, and its application to the design of a GS-based AAC system represents a novel. The infusion of frameworks from allied health and rehabilitation (as well as other fields such as education and linguistics) into the design approach may hold merit to guide the design process of GS-based AAC systems.

Although the HCD framework has been suggested to be a desirable approach in the design of AT devices [21,29], the use of HCD was rarely reported. Although there has been a move away from the use of UCD [21,22], many authors still reported following this approach - more so than HCD. Terminology confusion may result in designers and researchers mistaking HCD and UCD as the same approach [4,21]. HCD evolved from UCD and thus there are many similarities in the design processes and methods used. However, the key difference is the role of stakeholders within the design process [20]. Therefore, the decision to follow UCD may be because it is easier to involve users within the design process as subjects (i.e., as sources of information), and primarily during the evaluation stages with little involvement at the early stages of design [29]. This differs from HCD as individuals are seen as holders of experience and are thus involved in a collaborative manner throughout the design process, particularly during the earlier stages of the design process [20]. However, such collaborations may be complicated, particularly with users who have CCN [30].

There is a need to be more transparent about the type of design approach used. Inconsistent use of terminology leads to confusion and difficulties in consolidating the literature [4]. The various HCD approaches described by Steen may be considered more pertinently in AAC system design studies in the future, as the roles of users and stakeholders can vary along a continuum. By choosing a particular HCD approach, designers may be able to plan and articulate more clearly the role that stakeholders and users should play in the design process, thereby avoiding seemingly haphazard and ad hoc involvement that is not guided by a particular approach. At the same time, it may be helpful to acknowledge that the design of AT products and specifically of GS-based AAC systems may benefit by drawing also on frameworks and models from the field of rehabilitation, allied health, education, and linguistics.

Regarding the second aim, it was interesting to note that all authors considered (at least to some extent) some of the HCD principles, even though HCD was not pertinently mentioned in many studies. However, once again, the degree to which this was done and the degree to which it was described in the studies differed substantially. Principle # 1 states that the user, task and context need to be clearly understood. However, many studies in this review discussed the population, the task to be accomplished and the context of use in a general and somewhat superficial manner. This included broad statements such as designing systems for persons with communication and speech impairments to improve their face-to-face communication tasks within multiple day-to-day contexts [45,46,48]. This approach to identifying user requirements allows the product to accommodate for a wider range of individuals and decreases the chance of over-emphasising the findings from a small number of users [19,62]. However, the approach does run the risk of omitting specific needs of individuals with specific functional capabilities and limitations, such as a visual, cognitive or motor impairment [63–66]. Likewise, the design of systems for a specific diagnostic group (e.g., individuals with autism) runs the risk of assuming that all individuals with this diagnosis have similar needs and is reminiscent of a medical model approach where persons with disabilities are defined by their diagnosis. The International Classification of Functioning, Disability and Health (ICF)[67] has represented one attempt to move away from a purely diagnosis-based description of persons with disabilities to consider how the person's functional abilities are enhanced or hindered in specific environments to manifest in a higher or lower level of participation. Feature matching models of AT, such as the 'Matching Persons to Technology' or MPT model [14], emphasise the need to understand functional abilities of the person in need of the AT. Only four studies gave additional descriptions about some of the target user group's functional abilities, such as level of literacy, language impairment, and motor skills. One of the challenges that AT designers and developers face is the heterogeneity of the target user group, and the constant tension between the design for one and the design for everyone [2].

While language of the user group was mentioned in most studies, cultural considerations (e.g., appropriateness of the graphic symbols) were only pertinently mentioned in four studies. Culture is generally understood as incorporating the knowledge, ideas, beliefs, customs, and social behaviour of a particular group of people or society. Communication and specifically communication mediated by graphic symbols is likely to be heavily influenced by cultural conventions and expectations [68]. There may have been an assumption by many authors that they were insiders to the culture of the end users and stakeholders, and that their designs would automatically be culturally appropriate – therefore this aspect may not have been consciously considered. At the same time, it is likely that conventions in the fields of design, assistive technology design, and communication interventions are influenced by global and specifically Western culture and models of thinking [69]. It may still be necessary to critically interrogate both design processes and designed products for cultural congruence.

The focus on expressive communication as the task to be accomplished with the help of the designed system is understandable, in view of the difficulties that most persons with CCN experience in this regard. Communication remains one of the most complex human behaviours and manifests differently depending on the partners, purposes, and contexts involved. Task parameters therefore differ from interaction to interaction [70]. Light [71], for example, described how the social purpose of communication predicts the expectations partners may have about the specificity of the content and the rate of interaction, and the tolerance they may have for breakdown. The design of the GS-based system may or may not be conducive to allow users to meet the different expectations of different types of expressive communication tasks. In general, there seemed to be somewhat limited evidence of designers' awareness of the complexities of expressive communication and its multifaceted manifestations, and of the implications this may have for the design of a GS-based system.

The focus on narration by three studies may reflect the experience that this is often a particularly challenging task for persons with CCN who rely on GS-based systems [72–74]. Interestingly, the systems designed for this purpose did not contain the traditional grid displays but rather contained images presenting scenes, that could be viewed in a sequence. The difficulties that some users (e.g., those with aphasia) experience when attempting narration using GS-based AAC systems with a grid display has led some designers to focus on completely novel systems and approaches that include data-to-text capabilities [72] and video recordings [73].

There was a limited focus on improving language and literacy skills through the use of the system designed. Most systems were aimed at improving communication. This may suggest that limited communication is typically the overriding reason for introducing an AAC system, whereas language and literacy development may be secondary concerns. At the same time, language is the most sophisticated tool for communication that humans possess, and literacy is one manifestation of language that, unlike oral speech, may well be potentially achieved by some children with CCN [75,76]. A such, pertinent questions about the design of a GS-based system that may foster these skills should be asked [77,78], and designers would do well to consider this in the design process. As language and literacy acquisition proceed slowly over time, systems that allow team members (e.g., speech-language pathologists or educators) to continue expanding and adjusting the system over time in step with the user's skills are helpful. At the same time, the initial system design needs to make provision for such expansions (e.g., the possibility to allow end users to modify words morphologically). Open-source software [79] allows stakeholders even greater possibilities for modifying and customising the applications themselves – Pino et al. [79] give an example whereby so called technology integrators 'build' individualised systems, choosing from a variety of components (e.g., word prediction, text-to-speech, email communication, etc.) to customise an AAC application specific to the user.

The context of use was mostly either not specified or generally described to range across all daily interaction contexts. Designers seemed to acknowledge that communication pervades many of the daily activities of all humans in their intention to design AAC systems that support communication in all contexts. At the same time, this approach may run the risk of failing to acknowledge contextual influences on communication, and differences, for example, between home talk and school talk [80]. Designed system may therefore not always be suitable to truly support communication in all contexts. Norrie et al. [81], for example, conducted an ethnographic study in special education settings to identify AAC system design considerations that would increase the use and uptake of such systems in the classroom context.

The involvement of stakeholders (Principles #2, #3, and #5) in all the included studies was a positive outcome from this review. It was furthermore noteworthy that stakeholders were not only involved in the product evaluation stage, but also in the initial information gathering stages of the design process. According to Allsop et al.[82], the inclusion of the individual and their relevant stakeholders in the early stages of the design process is a key factor in AT system design, as it can ensure that the systems designed match the individual's needs, abilities and desires, which can ultimately increase usability. Although desirable, it is not always achieved, as the task of visualising an abstract concept of an intended product in the initial stages may be difficult for stakeholders [1].

Many studies consulted more than one stakeholder, which included the individual with CCN, as well as professionals (e.g., SLPs, occupational therapists, and educators), the parents/caregivers or other family members [51,83]. Hirotomi [50] was the only author who reported on including the users' peers as stakeholders within the design process. While the inclusion of multiple perspectives throughout the design process may benefit designers in gaining more information that can potentially influence the outcome of the system, collecting and incorporating this information into a single design may be challenging [1]. Therefore, the extent to which stakeholder contributions are incorporated into the design will differ depending on the experience of the designers, as well as the design requirements [82].

Stakeholders played different roles in the design process, and in various instances different stakeholder groups did not play the same role and were not necessarily consulted within the same stage of the design process of a specific system. Most stakeholders played an informative role in the design process, whereby the designers gained user and/or system requirements using techniques such as observations, questionnaires, interviews, and experience prototyping. Few studies included stakeholders in a participatory or collaborative manner. Actively engaging stakeholders within a design needs much consideration, and, although it was rarely stated in the studies reviewed, contextual factors such as time and money [1,28] may be reasons for stakeholders playing a smaller, informative role within the design of GS-based systems.

Communication challenges of persons with CCN may likewise lead to limited or no involvement in the design process [53,64,84]. In some cases, proxies may be involved instead of the user, as seen in Boyd-Graber et al. [38] and Mahmud et al. [53]. Assuming that the proxy will provide user-specific information runs the risk of not truly capturing the target individuals' needs and preferences [82,85]. For instance, the accuracy of the stakeholder's predictions of what the user may want to communicate may differ depending on the amount of time stakeholders spend with the individual and whether they engage in similar activities/tasks within a given context [85].

To facilitate user input, creative and novel ways to circumvent communication challenges are needed [16,23]. It is surprising how few studies within this review considered the need to obtain input in non-conventional ways. In future studies, designers may consider employing communication support strategies such as Talking Mats ™ that have been documented to be successful in helping persons with CCN to share their goals, desires and opinions [85,86]. Further research exploring how to adapt design methods to support the involvement of persons with CCN within the design process is required.

It was furthermore notable that none of the AAC systems designed were evaluated with a published scale or questionnaire developed specifically for AAC or even for AT in general. In their review, Tao et al. [65] found a multitude of formally developed instruments specifically for the evaluation of AT, including 26 instruments developed to evaluate AT related to digital media and communication. Yet most system evaluations made use of other methods or custom-developed scales and questionnaires for evaluation.

A focus on usability and particularly performance in specific controlled tasks was noted in product evaluation. Fewer instances of evaluating product acceptance and satisfaction were identified. A tendency to focus on usability rather than user experience (i.e., the sociological and psychological dimensions of using AAC) has been noted in the AAC literature and has been suggested to be one of the reasons of system underuse or abandonment [37,87]. Expanding the stakeholder role to a more collaborative one may be able to assist to focus on not only usability but also user experience throughout the design process.

Only half of the reviewed studies mentioned iterations (Principle #4) in the design process. A truly iterative design process allows a product to be shaped by the cycle of design, evaluation and redesign [22]. As early as 1985, Gould and Lewis [88] emphasised the importance of iterative design for ensuring excellent systems. Their study showed, however, that many designers saw it as too time consuming and expensive, and therefore impractical to implement. The current review suggests this may also be the case in various GS-based AAC system design processes.

Team members from various disciplines were involved in many of the reviewed studies (Principle #6). Multidisciplinary teams create the potential for pooling expertise in the design process in order to create a product that is truly usable, user-friendly, acceptable and desirable [60]. The mobile technology revolution with the concomitant proliferation of AAC apps has opened up the playing field for designers from various backgrounds, whereas AAC system design was limited to AT manufacturers before [89]. Despite diversity of design team members, the majority of the authors were affiliated to the disciplines of computer science and engineering. These disciplines typically dominate the field of AT technology design [90]. However, AAC professionals, such as SLPs and educators, have a crucial role in the assessment, selection and implementation of AAC services [91]. As such, it would be desirable to have such professionals as prominent team members in GS-based AAC system design research and development, along with designers, computer scientists, programmers, and engineers [30,90]. Productive involvement of team members from various disciplines in the design process requires skilful team leadership and a willingness to expand disciplinary horizons and transcend disciplinary conventions [15].

Limitations

As acknowledged in the first paper, limitations of the search strategy (e.g., focus on English records only) may have resulted in some studies being missed. Specifically the exclusion of grey literature precluded the inclusion of information from blogs or websites, where companies developing AAC systems may be more likely to offer information about the design of their products. The requirement that one paper should report on the whole AAC system design process may have resulted in the exclusion of design studies that were published in multiple papers. The lack of quality appraisal resulted in the inclusion of studies of varying quality. Authors did not always describe all aspects of the design process in detail, and inconsistent use of terminology also made consolidation of the literature challenging at times.

Extracting data based on specific concrete categories related to the six HCD principles (e.g., the stakeholder group involved, the stage of their involvement, and the manner in which their feedback was obtained) precluded a more nuanced and interpretive analysis of the way in which designers and authors incorporated HCD principles. A qualitative approach (e.g., thematic analysis) may have resulted in a deeper level of analysis. In addition, as is typical of a scoping review, many aspects of the included studies were described without going into much depth on any specific aspect. It would be possible to analyse the different aspects in more detail and with more rigour. For example, product evaluations could be described by analysing the specific methods, constructs evaluated and participants involved in a more rigorous manner.

Recommendations for further studies and design projects

Additional descriptive studies may be helpful to understand in more detail the processes that are used to engage stakeholders in the design of GS-based AAC systems. Methods could include a review of grey literature such as blogs and company websites, interviews with developers as well as surveys of the industry. Future design studies, in turn, may benefit from following an HCD approach in a more overt, conscientious manner. This may give structure and theoretical grounding to the approach used, rather than appearing reactive and somewhat ad hoc at times. It may also encourage designers to be intentional about stakeholder involvement, and carefully plan methods in which stakeholders can become not only informants, but active collaborators. In this regard, it is particularly important to consider how the adaptation of traditional design methods can facilitate the active involvement and accuracy of feedback of persons with CCN within a GS-based AAC system design process. Likewise, designers would do well to gather experts from multiple disciplines to be involved in the design process.

Product evaluation should consider not only usability, but also user experience. At present, there is little conformity in the constructs evaluated or the methods used to do so. A consolidation of GS-based AAC system requirements based on a defined conceptual framework may be worth attempting, in order to formulate tentative design standards and enable more robust product evaluation and comparisons. However, the heterogeneity of user groups and the complexity of communication as a task would make this an ambitious undertaking.

Conclusion

The complexities of designing a GS-based AAC system for the benefit of person with CCN and their communication partners require a multidisciplinary design team, a clear understanding of the users, their communication tasks and contexts, and close and continuous collaboration with stakeholders throughout iterative design cycles. Because HCD as an overarching design approach embodies all these principles, it has great potential to be productively applied in the design of these systems. However, a review of the current literature suggests that its application is still limited, with many designers not overtly following a specific HCD approach. One reason could be that designers are unaware of various specific HCD approaches. Another reason may be that AAC system design projects require designers to be flexible and adapt to the constraints of logistics and practicalities such as stakeholder availability, time, and cost. Being confined to a specific approach may limit such flexibility. While most design teams consulted and involved stakeholders (including users), their role was often primarily informative rather than collaborative. Greater collaboration with various stakeholders and their inclusion as part of the design team may lead to more robust products that are not only usable, but satisfying and acceptable by all stakeholders. Creative communication and participation supports are needed to ensure that persons with CCN can productively participate in the design process.

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