State of the Art in AAC: A Systematic Review and Taxonomy

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ABSTRACT

People with complex communication needs (CCNs) can use high-tech augmentative and alternative communication (AAC) devices and systems to compensate for communication difficulties. While many use AAC effectively, much research has highlighted challenges – for instance, high rates of abandonment and solutions which are not appropriate for their end-users. Presently, we lack a detailed survey of this field to comprehend these shortcomings and understand how the accessibility community might direct its efforts to design more effective AAC. In response to this, we conduct a systematic review and taxonomy of high-tech AAC devices and interventions, reporting results from 562 articles identified in the ACM DL and SCOPUS databases. We provide a taxonomical overview of the current state of AAC devices – e.g. their interaction modalities and characteristics. We describe the communities of focus explored, and the methodological approaches used. We contrast findings in the broader accessibility and HCI literature to delineate future avenues for exploration in light of the current taxonomy, offer a reassessment of the norms and incumbent research methodologies and present a discourse on the communities of focus for AAC and interventions.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**; **Accessibility technologies**.

KEYWORDS

AAC, Alternative and Augmentative Communication, Systematic Review, Taxonomy, Accessibility.

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1 INTRODUCTION

Approximately 2.2 million people in the UK and 1.3% of the US population experience a form of communication impairment [18]. Critically, challenges in human social and communication skills subject individuals to many risks such as: negative social interactions [122], employment challenges [156], educational access [48], mental health disorders [76] and a myriad other challenges [131]. Equally, communication and freedom of speech is protected under UN legislature [120] and revered as the very "*essence of human life*" [105]. Aided and unaided AAC strategies and systems serve to remediate communication difficulties experienced by individuals and communities with complex communication needs (CCNs) [126]. In particular, high-tech aided AAC devices encapsulate the most advanced electronic AAC technology for example speech generating devices (SGDs) or voice output communication aids (VOCAs) [42]. Data on the prevalence of specifically high-tech AAC is limited, however there will be an increase in the number of individuals requiring AAC interventions [9, 107, 135]. Also, there has been sustained academic research into high-tech AAC devices and interventions since the formation of the International Society for AAC (ISAAC) in 1983 and the AAC journal in 1985 [155, 183]. Since then, high-tech AAC has been developed to support wide age ranges [106] and serve many communities [135]. In many cases, high-tech AAC devices and interventions have contributed to positive and successful outcomes for individuals with CCNs whilst advances in computer technology, machine learning (ML) and artificial intelligence (AI) hold much promise for future high-tech AAC [140, 185].

1.1 High-tech AAC Device Abandonment and Fellow Systematic Reviews

Numerous HCI researchers, including Bircanin et al. [20], Ibrahim et al. [81], Norrie et al. [140] have noted that high-tech AAC devices too often experience a high rate of abandonment amongst their target community. The reasons for abandonment of high-tech AAC devices are far ranging and vary dependent on the community and intervention circumstances [140]. However, research has found that high-tech AAC devices can be frustrating to use, unreliable, slow [92, 140] and ineffective for certain common communication interactions leading to breakdowns and misalignments [81, 92]. Other problems noted by research include that high-tech AAC devices carry a stigma [128], are too expensive [65], hard to program [33] and inconsiderate of cultural factors [100] – making high-tech AAC devices simultaneously challenging for their users, close caregivers, specialists and wider communities to adopt. At the same time high-tech AAC has often been found to inadequately adapt to their users communication strengths and weakness or offer pathways for multimodal or embodied forms of communication [81]. In light of these criticisms, we believe it is important to reflect on the full body of high-tech AAC research with a systematic review (SR) of the literature and taxonomic overview of devices

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fostering novel pathways for improving high-tech AAC devices, interventions and research.

There are several pre-existing SRs into AAC, which typically focus on research interventions for specific communities and groups. Beukelman et al., studied AAC interventions for adults with neurological conditions [17], Biggs et al., reviewed interventions for children with CCNs [19], both Holyfield et al., and Logan et al., examined AAC interventions amongst people with autism (ASD) [77, 111], van der Meer et al., analysed interventions for individuals with developmental disabilities (IDDs) [182] and Simacek et al., focused on AAC interventions amongst individuals with multiple disabilities [165]. Lastly, Moorcroft et al., assessed research on barriers in the provision of low-tech and unaided AAC [130]. Some SRs have even focused specifically on high-tech AAC devices and interventions. Baxter et al., conducted two reviews of high-tech AAC interventions, barriers and facilitators [11, 12]. Whilst, the remaining high-tech AAC reviews focus on interventions in specific communities and groups. Morin et al., provided a meta-analysis of AAC interventions for people with IDDs [131], Still et al., examined interventions for people with ASD [170] and lastly Ju et al., considered high-tech AAC interventions amongst ICU patients [89].

Despite this previous research, at present there is not a broad survey of the literature including analysis of the earliest and latest high-tech AAC research. Consequently, this review and taxonomy will look to supplement the following three research gaps vacated by the previous SRs. Firstly, previous SRs were focused on clinical practice over HCI and device-orientated development – failing to establish a taxonomy of high-tech AAC, which supports the development of future generations of devices. Secondly, previous SRs did not track the prevailing research methods and capture data on the studies undertaken. Thirdly, previous SRs have not captured broad data on which communities have comparatively currently received the *most* high-tech AAC research. Additionally, the SRs predate the recent criticisms of high-tech AAC (c.f. [20, 81, 140]) and offer no comparison with the Mack et al. findings from reviewing accessibility research [112].

1.2 Research Questions and Contributions

To focus our contribution we initially developed three research questions:

RQ1: What is the current taxonomy and dominant characteristics of high-tech AAC?

RQ2: What research methods are used to contribute towards the design and study of high-tech AAC devices and interventions?

RQ3: Who does high-tech AAC devices and interventions focus on?

The three research questions support the review and analysis of previous high-tech AAC research – quantitatively evaluating the design of devices, methodologies and communities of focus. The research questions capture data to enable the identification of notable research gaps, development of strategic directions for future research and support cross-comparison with the Mack et al., research [112]. Thereby supporting *more* novel, successful and long-term high-tech AAC interventions. To answer these three research questions, mapped in Figure 1, we have four contributions in this paper:

(1) We have built an open-source data-set of 562 coded papers from 1978-2021 focused on research into high-tech AAC devices and interventions encompassing peer-reviewed articles using 2021 PRISMA guidelines [153].
(2) We present the first SR and taxonomy of high-tech aided AAC devices within the ACM literature. The taxonomy of high-tech AAC was developed in three ways: (a) collecting an inventory of the interaction experience through coding high-tech AAC devices' input and outputs (b) understanding the features of high-tech AAC devices through coding the interface layout and scalar attributes (c) understanding the communication facilitated via coding the communication model/type facilitated by the device.
(3) We provide an analysis of the methodologies, roles, and communities of focus within high-tech AAC interventions and research. This data is then cross-analysed with the Mack et al. SR of accessibility research [112], which we consider to be normative standards for accessible computing research – to gain an understanding of similarities and differences with wider accessibility research.
(4) We provide implications for future research on high-tech AAC devices and interventions. In the discussion, we identify directions for future scientific investigations and high-tech AAC development. With almost 40 years of preceding research, we consider this contribution significant for new researchers to improve the development of future high-tech AAC devices and decrease the current high rates of abandonment [81].

2 BACKGROUND AND RELATED WORK

We outline the key related work on SRs of high-tech AAC and frame our work in communication research; discussing the models and types of communication for developing the codebook.

2.1 Related Work in High-tech AAC

Although no SR and taxonomy of high-tech AAC has been published within the ACM literature, previous research has explored the design and barriers of high-tech AAC [11, 12, 166]. Plus, previous research has considered specific sub-areas including high-tech AAC interventions for aphasia [181], autism [170] and ICU patients[1] [89].

2.1.1 Related Taxonomies and Investigations of AAC Design and Barriers. The closest contribution to a taxonomy for high-tech AAC is a paper by Belani presenting a usability requirements taxonomy for mobile AAC services [14]. Belani's taxonomy inherits from systems engineering and focuses on accessible software principles: the context of AAC usage, user relations and the principles of simplicity, supplementing and trustworthiness [14]. Furthermore, this taxonomy tries to develop a set of augmentative requirements differing from our systematic investigation of the pre-existing literature and consequent device taxonomy[2] [14, 30]. Barriers and facilitators of

[1]Critical research has considered the efficacy of high-tech AAC through consumer perspectives [24] and as an evidence based practice [131].
[2]See Brudy et al.'s, taxonomy of the cross-device computing domain [30].

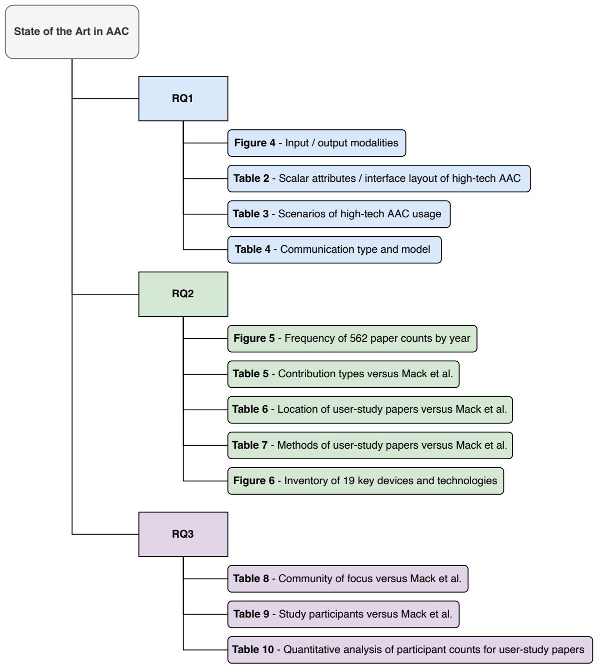

Figure 1: Flow diagram presenting an overview of the figures and tabular contribution towards each research question. 1.2: Figure 4 and Tables 2, 3, 4. 1.2: Figures 5, 6 and Tables 6, 7, 8. 1.2: Tables 9, 10, 11.

high-tech AAC are explored in 2 SRs by Baxter et al. [11, 12]. In their first SR of 27 papers, they identified several key themes – 11 papers described the limited reliability of high-tech AAC devices, 8 papers highlighted the difficulties of learning how to operate devices and 6 papers discussed inappropriate voices/words generated by devices within specific cultural contexts[3] [11]. Turning to their second and more extensive SR of 65 papers and interventions from 2000-10 [12]. In order of frequency, Baxter et al. report that the most common community of focus for high-tech AAC interventions were 14 studies focused on aphasia from non-progressive causes, 13 focused on interventions with people with autism disorder (ASD), 12 considered interventions for adults with cerebral palsy whilst other communities faced a smaller subset[4] [12].

2.1.2 Sub-areas of High-tech AAC. SRs considering sub-areas of high-tech AAC interventions to a greater extent report optimistic results. For people with aphasia (PWA), Sandt-Koenderman's SR emphasised the need for AAC devices to be "tailor made", taking advantage of PWAs residual language skills and communicative strengths [181]. In contrast, Still et al. perform an SR focused on high-tech AAC interventions for individuals under the age of sixteen with ASD [170]. They found portable SGDs have been frequently favoured for interventions – in particular, iPod and iPad-based applications and intervention results were positive for teaching requesting skills [170]. Within a hospital setting for voiceless ICU patients, Ju et al. performed an SR considering adoption and effects of a high-tech AAC intervention [89]. From the 18 studies qualitatively synthesised with the *TAM model*, they found that high-tech AAC was easy to learn and use in most studies – with customisation and portability of devices most important for patients [89]. For future positive development of high-tech AAC technologies, they encouraged further collaboration directly with ICU staff and patients [89]. Although not specifically high-tech AAC research, broader accessibility scholarship has offered meaningful reflection that should shape future high-tech AAC interventions. Scholars have accepted the importance of not "*medicalizing*" disability[5] [45, 112]. In this vein, AAC devices should *not* serve as assistive technologies to *fix* people living with communication disorders. Bennett et al. [15] have effectively conceptualised this form of technology through a notion of *independence* – in which the high-tech AAC device itself incorrectly serves as a dependent interface to communicating with the environment and others[6] [15]. Instead, we believe high-tech AAC should be guided by Bennett et al.'s *interdependence framing* of assistive technology (AT) – reframing high-tech AAC as an assistive technology (AT) that *all* can freely engage and leverage to interface and communicate with the environment [15].

2.2 Models and Types of Communication

High-tech AAC is developed based upon our understanding of communication and models of successful communication exchanges between human parties. Here, we discuss three recognised models of communication and two types of communication – this scholarship directly influenced the categories and sub-codes used in our taxonomy of devices and high-tech AAC codebook.

2.2.1 Models of Communication. The *most* basic model of communication that high-tech AAC can support is the original model of communication i.e. Shannon-Weaver sender-receiver or *Linear model* [161]. The model consists of just four parts[7] and mirrors the functioning of radio and telephone technology – for instance the sender delivers a message using a high-tech AAC device, the channel is the AAC device speaker, and the receiver hears the sender's message [161]. Within this model, information is solely transmitted between the two parties. Yet, Ibrahim et al., have criticised high-tech AAC devices that exclusively support sender-receiver and linear communication [81]. Emphasising Kraat et al.'s research [98] , Ibrahim et al. argue that high-tech AAC communication should be much more dynamic made up of people, the setting, rules of language use and situated within the context [81]. In contrast, the *Interactive model* offers more dynamic communication. Here, high-tech AAC supports the feedback flow between sender and receiver

[3]Secondary themes from the research include needs for staff training, limitations of technical support, decision difficulties faced by families whilst selecting an AAC device and negative communication rates with the AAC device [11].
[4]Other findings of the research include that devices were found to be beneficial in enhancing communication across a broad range of diagnoses and age ranges [12].
[5]Mankoff et al., has called for greater representation of disabled people in accessibility research – in the same vein as Mack et al., we provide some empirical metrics of representation within our dataset [112, 114].
[6]Limiting the AAC users' autonomy, perpetuating social stigma and increasing marginalization by exacerbating social differences.
[7]These parts are: (1) sender, (2) message, (3) channel, and (4) receiver.

– feedback can be verbal (i.e., "yes" or "no" or nonverbal i.e., a nod or smile) [190]. However, the feedback provided by the high-tech AAC is not simultaneous and can be potentially slow or indirect. Lastly, the *Transactional model* is the most dynamic – senders and receivers are now considered communicators [10]. Now, high-tech AAC communication is a co-created process with instantaneous feedback between parties [10]. Although challenging, high-tech AAC must look to support interactive and *even* transactional communication where communication is an embodied, meaningful and multimodal experience for its users [81].

2.2.2 Types of Communication. Broadly there are two exclusive types of communication, which high-tech AAC can enrich: nonverbal and verbal[8]. Verbal communication is the use of words to convey a message whether that be written or dialogue [84]. Examples of verbal communication include oral forms i.e., speech and written forms e.g., letters and text messages [84]. In contrast, non-verbal communication explains the processes that convey a message in a form of non-linguistic representations [75]. Examples of non-verbal include gestures, sign language, facial expression, and eye contact [75]. Most high-tech AAC devices do not equally support both types of communication. High-tech AAC to augment and enhance users' verbal communication has taken precedence over supporting non-verbal forms [180]. Instead, high-tech AAC should consider and enhance *both* types of communication for successful outcomes [80]. For instance, Valencia et al.'s physical expressive objects successfully increase augmentative communicators (ACs) agency in conversations with unfamiliar partners using *solely* non-verbal messages and signals [52, 180].

3 METHODS

In this paper we followed PRISMA 2021[9] procedures for SRs [153] with secondary support from Siddaway et al. [162] and Silva et al.'s SR guidelines [164]. Firstly, we consider the scope of our investigation via defining high-tech AAC. Secondly, we discuss methods for creating a dataset using PRISMA guidelines. Thirdly, we describe the qualitative, quantitative and programmatic analysis methods of this study.

3.1 Scope

We start by presenting our definition of high-tech AAC devices and interventions. AAC comes in many forms to support a variety of communities and needs - therefore a clear definition for the scope is significant [18]. Unaided AAC interventions use *no* equipment i.e., signing or body language [130]. For unaided AAC research there are several pre-existing SRs, such as: [130]. By contrast, aided AAC interventions encompasses any enabling aids or technologies used to support or replace communication for those with CCNs thereby enriching the production or comprehension of communication [126]. However, this equipment comes in a wide variety of form factors [18]. Aided AAC devices are categorised as no, low, medium and high-tech [18]. Low-tech AAC devices do not require electricity or battery power [130]. Typically, they are simple props to foster communication such head/mouth sticks to enable pointing, pen, paper, and eraser boards for drawing or writing to even customised analogue systems such as communication boards and books [130]. Medium-tech AAC devices encapsulate very *simple* electronic devices with basic technology [142]. Examples include battery powered switches or buttons that communicate one or two messages, an LED light, or appropriated technology devices such as motion toys, radios, and fans [142]. Therefore, high-tech aided AAC devices encapsulate the most advanced electronic AAC technology with multi-message vocabularies – for example, SGDs or VOCAs [17]. High-tech AAC devices vary in shape and size, potentially with dynamic displays for depicting letters, words, phrases, pictures and/or symbols that the communicator navigates to express messages [4]. They differ in size, weight, and portability as well as access methods – either *direct* selection of a screen/keyboard with a body part, pointer, or eye gaze adapted mouse/joystick or *indirect* selection forms such as switches and scanning [18, 46, 142]. Our operational definition of high-tech AAC is established by the following three requirements:

- Req1: Our scope addresses AAC research. AAC encompasses tools and strategies that individuals use to supplement communication [42]. Communication is multimodal and takes many forms i.e., speech, glance, text, gestures, facial expressions, sign language, symbols, pictures, SGDs etc. contingent upon the context and communication partner [98].
- Req2: The paper must research *aided* AAC interventions and devices. Aided AAC serves as hardware or software that is used to supplement, enrich, or replace communication. Aided AAC can take many forms and is categorised as low, medium or high-tech.
- Req3: The paper must address *high-tech* aided AAC interventions. High-tech AAC refers to any AAC hardware, device, tools, software or technologies powered by electricity that permits the storage and retrieval of *multiple* electronic messages to support or enrich the users communication.

Requirements 3.1 to 3.1 specify the scope of our investigation. We wanted to focus on AAC research for individuals with CCNs. However, within this broad domain, we narrowed towards aided AAC tools and devices deliberately designed to enrich verbal and nonverbal communication rather than unaided forms or systems. Equally, we wanted to focus specifically on high-tech aided interventions, meaning our scope avoids appropriated devices or low-tech forms of AAC.

3.2 Dataset Establishment

There are many ways to conduct SRs, but to derive solutions for our three research questions (i.e., 1.2– 1.2) we harnessed methods detailed in PRISMA 2021 guidelines for reporting meta-analyses [153]. We describe in detail the following: *identification, screening, eligibility* and *snowballing* depicted in Figure 3.

3.2.1 Identification. The role of the identification stage is to capture work that addresses the three research questions by performing queries of the relevant scientific databases. We chose the ACM DL[10]

[8]Sometimes re-conceptualised with more types of communication considered such as written or visual.

[9]The PRISMA acronym stands for Preferred Reporting Items for Systematic reviews and Meta-Analyses.

[10]https://dl.acm.org

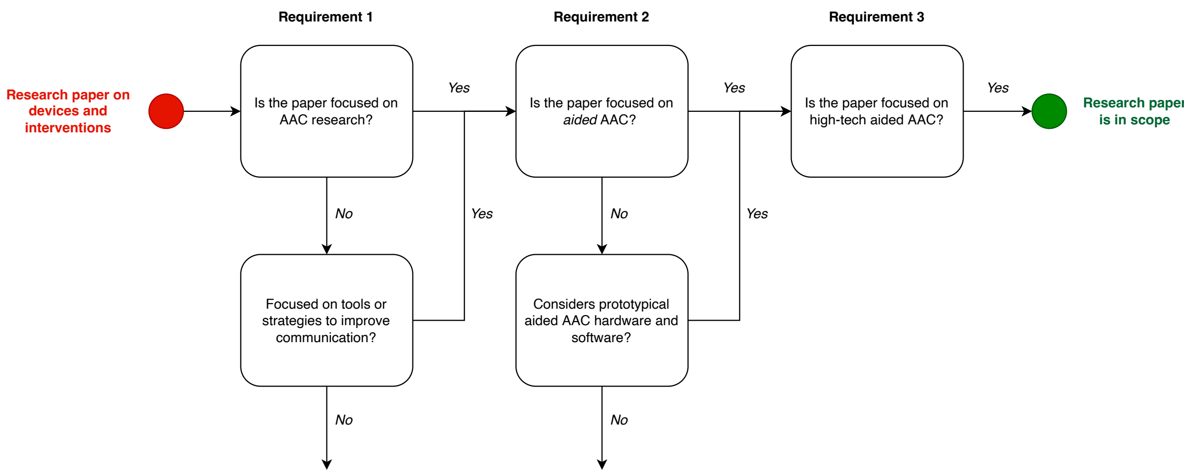

Figure 2: Flow diagram providing the scope of our investigation on high-tech AAC devices and interventions. For greater detail please refer to 3.1, 3.1 and 3.1 detailed within the text.

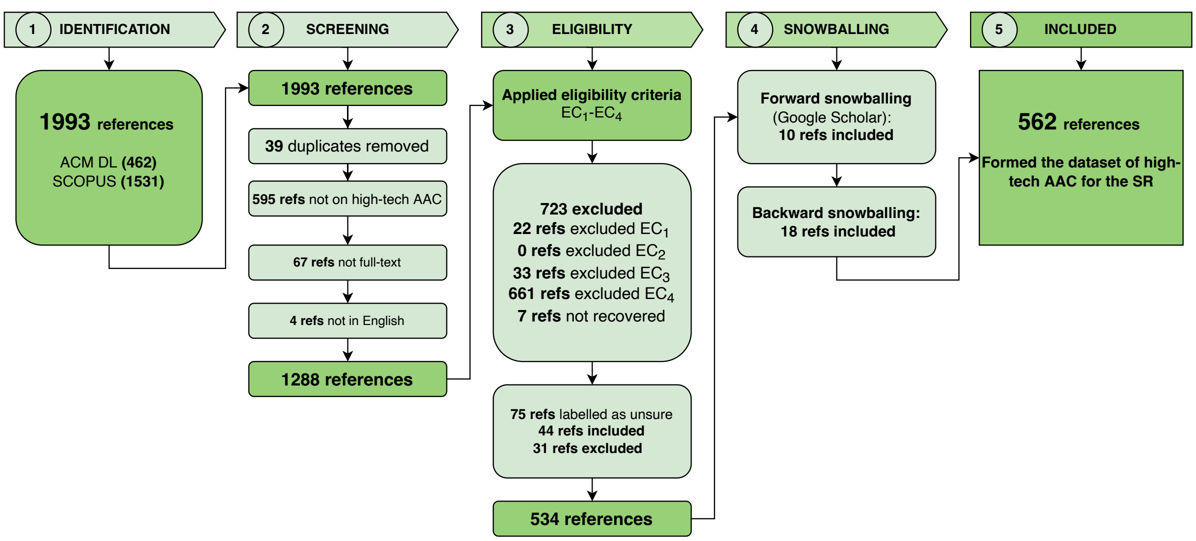

Figure 3: The PRISMA diagram [153] illustrating the reference frequencies of identification, screening, eligibility, snowballing and inclusion stages of our SR and taxonomy of high-tech AAC devices and interventions.

and SCOPUS[11] as two major electronic databases for Computer Science and AAC research. Initially, we performed some preparatory searches to broadly investigate the search space – before committing to a definitive search strategy. From this initial investigation, we identified that the ACM database provided essential HCI papers yet failed to include key research papers from the academic literature – such as the AAC journal. In contrast, SCOPUS offered a broader search space containing literature from the AAC journal and several other prominent venues for high-tech AAC literature. For deciding keywords, we performed an analysis of the research questions and extracted initial keywords – utilising these, we then collectively iterated several times to produce synonyms for *more* keywords including acronyms and common named high-tech AAC devices e.g., *voice output communication aids* and *speech generating devices*. We then developed methods to avoid returning high quantities of false-positive papers – for instance, we decided to search *just* title, abstract and keywords. Additionally, within the search string we concatenated the keywords with *OR* plus *AND* connectors to ensure the ordering of the terminology was coherent and asterisks were liberally used to enable multiple and plural forms of the keywords. For the ACM DL, the final query was:

[11]https://www.scopus.com/

```
"query":
{
Title: ((aac) OR (augment* AND alternat* AND communicat*) OR (comput* AND
assist* AND communicat*) OR (voice* AND output* AND communicat* AND aid*)
OR (alternat* AND augment* AND communicat*) OR (speech* AND generat* AND device*)) OR
Abstract: ((aac) OR (augment* AND alternat* AND communicat*) OR (voice* AND output*
 AND communicat* AND aid*) OR  (alternat* AND augment* AND communicat*) OR (speech*
 AND generat* AND device*)) OR Keyword ((aac) OR (augment* AND alternat* AND communicat*)
OR (comput* AND assist* AND communicat*) OR (alternat* AND augment* AND communicat*) OR
(voice* AND output* AND communicat* AND aid*) OR (speech* AND generat* AND device*))
}
```

The ACM query returned 462 results. For the SCOPUS database we queried *solely* the title field because initial testing with the abstract and keyword fields resulted in too many false positives – meaning featureless, large search spaces exceeding 20,000 papers. Additionally, we performed an abstraction based on venue for the SCOPUS query to limit the state space and number of papers. The final relevant selected venues were titled with: AAC, technology, aphasia, language and communication disorder. Meaning the final SCOPUS query was:

```
(
TITLE-ABS-KEY(aac) OR TITLE-ABS-KEY(voice* AND output* AND communicat* AND aid*)
OR TITLE-ABS-KEY(speech* AND generat* AND device*) OR
TITLE-ABS-KEY(alternat* AND augment* AND communicat*) OR TITLE-ABS-KEY(augment*
AND alternat* AND communicat*)) AND (
LIMIT-TO ( EXACTSRCTITLE,"AAC Augmentative And Alternative Communication" )
OR LIMIT-TO ( EXACTSRCTITLE,"Lecture Notes In Computer Science Including Subseries
 Lecture Notes In Artificial Intelligence And Lecture Notes In
Bioinformatics" )
OR LIMIT-TO ( EXACTSRCTITLE,"Augmentative And Alternative Communication" )
OR LIMIT-TO ( EXACTSRCTITLE,"Disability And Rehabilitation Assistive Technology" )
OR LIMIT-TO ( EXACTSRCTITLE,"Communication Disorders Quarterly" )
OR LIMIT-TO ( EXACTSRCTITLE,"Assistive Technology" )
OR LIMIT-TO ( EXACTSRCTITLE,"International Journal Of Language And Communication Disorders" )
OR LIMIT-TO ( EXACTSRCTITLE,"Advances In Intelligent Systems And Computing" )
OR LIMIT-TO ( EXACTSRCTITLE,"Conference On Human Factors In Computing Systems Proceedings" )
OR LIMIT-TO ( EXACTSRCTITLE,"Topics In Language Disorders" )
OR LIMIT-TO ( EXACTSRCTITLE,"Technology And Disability" )
OR LIMIT-TO ( EXACTSRCTITLE,"Aphasiology" )
OR LIMIT-TO ( EXACTSRCTITLE,"Assistive Technology Research Series" )
OR LIMIT-TO ( EXACTSRCTITLE,"Communications In Computer And Information Science" )
OR LIMIT-TO ( EXACTSRCTITLE,"Journal Of Special Education Technology" )
OR LIMIT-TO ( EXACTSRCTITLE,"Studies In Health Technology And Informatics" )
OR LIMIT-TO ( EXACTSRCTITLE,"Communication Sciences And Disorders" )
OR LIMIT-TO ( EXACTSRCTITLE,"Pervasivehealth Pervasive Computing Technologies For Healthcare" )
OR LIMIT-TO ( EXACTSRCTITLE,"ACM Transactions On Accessible Computing" )
OR LIMIT-TO ( EXACTSRCTITLE,"International Journal Of Speech Technology" )
)
```

The SCOPUS query returned 1,531 papers in total. All queries were run on the 05/11/2021 and returned a combined 1,993 papers in total from 1978-2021.

3.2.2 Screening. A quick scan of dataset titles revealed that some of the 1,993 were out of scope and required manual removal during the subsequent process of screening. Firstly, we discovered 39 duplicates and eliminated them from our dataset. Secondly, we read titles, abstracts and keywords – removing papers not focused on high-tech AAC research. Consequently, 595 of the results were not papers within the research area and focused on factors such as: advanced audio coding e.g., [38], digital content distribution e.g., [95], communication routing algorithms e.g., [139] and proteins amino acid composition e.g., [188]. A further 67 results were clearly not full-text papers i.e., conference proceedings and 4 papers were removed for not being in English. Throughout screening, an explanation file was developed where the first author provided an index, reason, and explanation for the suggested removal of a paper from the dataset. Subsequently, the second author reviewed the dataset and explanation file for quality control purposes – to jointly discuss any highlighted papers promulgating uncertainty and verify removal suggestions made by the first author. Papers were then only removed from the dataset once the two authors had come to agreement. This screening process resulted in 1,288 papers remaining in the dataset.

3.2.3 Eligibility. Following PRISMA guidelines – we formulated a set of four eligibility criteria (3.2.3 through to 3.2.3) to further filter out work irrelevant to the scope of our systematic literature review and domain:

EC1: *Availability of full-text.* The full-text research paper is available and written in English to be accessible for the research team.

EC2: *Peer-reviewed academic research.* The research must be peer reviewed literature and academic. E.g., journal articles, conference papers, and PhD dissertations. Other media forms would be excluded.

EC3: *Aided AAC research and interventions.* The paper had to clearly focus on *aided* AAC interventions – an AAC aid is any device that is electronic or not, which is harnessed to transmit and receive messages. In contrast, *unaided* AAC interventions are those that do not require external tools e.g., sign languages.

EC4: *High-tech AAC interventions.* The paper must include research on high-tech aided AAC interventions. As defined earlier, high-tech refers to the most advanced forms of aided AAC – that being electronic devices that enable the retrieval and storage of electronic messages to support and enrich communication. There are a variety of high-tech AAC devices in a multitude of different forms: such as a dedicated device like a DynaVox e.g., [4], tablet and smartphone apps e.g., [124], brain computer interfaces (BCI) e.g., [59] and even wearables e.g., [54]. We wanted to incorporate as much of this emergent literature as possible to provide an encompassing analysis of high-tech AAC research.

The eligibility process involved the first author initially labelling papers as *in*, *out*[12] or *unsure*. Consequently from the 1288 papers – 490 papers were included, 723 papers were excluded for failing to meet eligibility criteria (3.2.3 to 3.2.3) and 75 labelled as *unsure*. Checks on the labelling were performed by the second author and followed by lengthy discussions on the *unsure* papers. Then from the *unsure* papers 44 were included with a further 31 papers excluded. Once all procedures were completed, 534 papers remained in the dataset for manual qualitative coding meaning in total 754 papers had been excluded.

3.2.4 Snowballing. Snowballing identified a further 28 papers on the topic of high-tech AAC consisting of peer reviewed literature from 1992-2021. Following guidance from Wohlin, we performed snowballing iterations until dead ends were reached and no new candidate papers were identified from forward or backward snowballing every paper [196]. The process of snowballing took 3 iterations until Wohlin's efficiency metric reached 0% [196]. Through this, we identified 44 potential candidate papers from titles and abstracts, yet upon further inspection all did not meet our eligibility criteria for inclusion. After applying these, *just* 28 papers were added to our dataset. Backward snowballing gave 18 papers by studying the references of selected papers. Forward snowballing

[12]Each paper labelled as out – failed eligibility criteria was noted.

presented 10 papers by studying the works cited utilising Google Scholar. After snowballing our dataset was 562 papers in total.

3.3 Analysis

Analysis involved qualitative coding of the entire dataset and calculating Fleiss's Kappa inter-rater reliability (IRR)[13] [53] to reach agreement between the three authors. Following this, we programmatically examined paper counts over the 43-year period, performed quantitative data extractions for participant counts, developed an inventory of key high-tech AAC devices and analyzed corresponding results found by the Mack et al., dataset [112].

3.3.1 Qualitative Analysis of the Dataset. We qualitatively coded all 562 papers from 1978-2021. The process of coding and analysing the dataset was performed by 3 scholars. We note that the procedure of building and analyzing the dataset involved subjectivity and we appreciate that our scholarship reflects our own biases and beliefs. Authors and coders identified as male and female of Western and Southern European backgrounds, with no accessibility needs. The codebook is synthesized to provide data for our three research questions (i.e., 1.2, 1.2 and 1.2). Shown in Table 1, the final codebook included 16 categories with 2-10 subcodes each. Out of the 16 categories, 8 were developed by the research team and 8 based upon the Mack et al., codebook for accessibility research [112]. The 8 categories adapted from the Mack et al., were to cross-analyse high-tech AAC research with current normative accessibility standards[14]. In contrast, the 8 categories from the research team focused on establishing a taxonomy and understanding of the dominant characteristics of high-tech AAC devices. We wanted to code the features and role of the device – its commercialism, inputs/outputs, scalar attributes, communication types/model and scenarios of usage. This data would taxonomise and provide an understanding of the current characteristics of high-tech AAC devices. The codes were iterated by two authors using an iterative inductive analysis approach – in which codes were independently developed and finally agreed between both parties. Indeed, the two authors would regularly meet – to refine and eliminate existing codes or add new codes. Qualitative coding took three months and IRR was calculated between the three authors – to mitigate against bias and fatigue. The second and third author retrospectively[15] coded a random sample of 10% (N=60) of the dataset to provide a Fleiss Kappa IRR and provide an opportunity for disagreements to be resolved through consensus.

3.3.2 Quantitative and Programmatic Analysis. For quantitative analysis, we programmatically analyzed paper counts for the full 43 year period and developed novel visualisations to demonstrate our findings. Following this, we performed an analysis of participants counts for user studies – calculating mean, median, interquartile range and standard deviation providing analysis for the entire dataset and each community of focus. Then we constructed an inventory of key devices regularly mentioned within the research and analyzed corresponding results from the Mack et al., SR into accessibility research [112]. However, we accept that a limitation of the comparison is that the Mack et al., dataset is from a more recent period of 2010-9.

[13] An extension of Cohen's Kappa for three raters or more [53].

[14] The identification of differences, advantages and limitations of high-tech AAC versus wider accessibility standards we believe will improve future high-tech AAC devices and interventions.

[15] The third author was new to the dataset and not involved in the code development process – resulting in a marginally lower IRR versus other papers [112].

4 RESULTS

4.1 A Taxonomy of High-tech AAC Devices and Interventions

We present results from the following 7 categories within our dataset of 562 papers: interaction input, output modality, scalar attributes, layout, scenarios/communication partners, communication model and communication type.

4.1.1 Input and Output Interaction. We successfully coded the inputs and outputs of high-tech AAC devices within the dataset (see Figure 4). Starting with inputs, the most frequent locus of research is mechanical (N=216, 38.4%) followed by tactile (N=184, 32.7%). Since the earliest high-tech AAC systems, mechanical inputs have come in a wide variety of forms. Examples include, switches [180], keyboards [157], button presses [125], mechanical pointing devices [125], trackballs [187], and joysticks [157]. Tactile inputs serve as a key input modality for touchscreen controlled hardware e.g., smartphones [124], tablets [124] and smartwatches. In contrast, camera (N=77, 13.7%) and gestural input (N=48, 8.5%) techniques have been explored to a lesser extent. However, cameras have been leveraged for different interactions: primarily to enable eye gaze [17], blink activated, head motion controlled high-tech AAC systems [17], equally to better design and configure AAC systems, to provide gesture recognition for sign language [70] and for photography to support contextual word discovery [91, 141], personalisation of VSDs [192] and even storytelling. Body gestures have been leveraged in different ways to control high-tech AAC devices. Systems have been designed that are controlled by tongue movement [143], musculature contractions [21], breath controlled [46], heart rate signals and brain computer interfaces (BCIs). BCIs have been developed for different brain signals such as EEG and EMG signals [86]. Recent advances have been made using BCI's such as P300-based, the RSVP Keyboard and BrainGate to enable individuals with a physical disability to use assisted communication interfaces [59, 148, 149, 178].

Contextual (N=31, 5.5%), and verbal inputs (N=29, 5.2%) are less explored in high-tech AAC. Contextual enables smart leveraging of environmental knowledge to act as an input to the high-tech AAC device [22, 99]. Knowledge of the context i.e., environment, location or communication partner have been harnessed in high-tech AAC systems for: natural language generation (NLG) [152], synthesised vocabulary searches, discourse prediction, improved adaptation to topics and to capture experiences [90, 91]. Verbal inputs can be used as another input for high-tech AAC devices – to provide utterance recognition [174], perform NLP on the communication partners dialogue [195], function as a voice input voice output device [72] and offer prosody on the wearer's dialect. Lastly, orientational input (N=7, 1.2%) serves as an underexplored input technique. Accelerometers have been harnessed to calibrate and improve the conversation rate of people with motor impairments [66], develop wearables to translate sign language in real time [8], for

Table 1: The final codebook is represented by 85 subcodes across 16 code categories. Retrospective qualitative Fleiss Kappa IRR calculated across the subcodes for each category between the three authors. IRR ranged from almost perfect to fair with a high pairwise agreement throughout.

Category	Codes	Pairwise agreement	Fleiss Kappa IRR	Level
Participatory design	Yes; No	90%	0.8	Almost perfect
Interaction input	Verbal; Camera; Tactile; Gestural; Mechanical; Orientational; Contextual	94.8%	0.789	Substantial
Ability-based comparison	Yes; No	85.6%	0.709	Substantial
Output modality	Audio; Visual; Motion; Gustation; Thermoception	91.3%	0.693	Substantial
Participant groups	No user study; People with disabilities; People without disabilities; Specialists; Caregivers	88.4%	0.667	Substantial
Communication model	Linear; Interactive; Transactional	85.9%	0.644	Substantial
Communication type	Verbal; Non-verbal	81.7%	0.622	Substantial
Use of commercial AAC	Yes; No	77.8%	0.553	Moderate
Contribution type	Empirical; Artifact; Methodological; Theoretical and opinion; Dataset; Survey	84.3%	0.543	Moderate
User study method	Controlled experiment; Randomized control trials; Survey; Usability testing; Interviews; Focus groups; Case study; Field study; Workshop; Other	90.4%	0.501	Moderate
Use of proxies	Yes; No	75%	0.5	Moderate
Community of focus	BVI; DHH; Motor/physical impairment; Autism; IDD; Other cognitive; Older adults; General disability; Other	88.2%	0.462	Moderate
Location	No user study; Near/at researchers lab; Home, residence or school; Neutral; Online/remote; Other	85.2%	0.455	Moderate
Scalar attributes	Morphable; Customisability; Automaticity; Expressivity; Adaptive; Practicality; Combined; Parallel	88.9%	0.447	Moderate
Interface layout	Symbols; Pictographic; Text; Animation; Grid; VSD; Novel; No layout	80%	0.442	Moderate
Scenarios and communication partners	Fellow AC; Family/friends; Professionals; Groups; Strangers; Anyone; Virtual; Unclear	87.9%	0.388	Fair

speech therapy, and to make apps more usable amongst children with disabilities [25]. Unlike inputs, outputs for high-tech AAC devices have been less widely explored. Audio signals dominant communication output (N=353, N=62.8%) – high-tech AAC devices tend to serve as SGDs, VOCAs and for speech synthesis. High-tech AAC outputting visual signals for the purpose of communication have also been well explored (N=157, 27.9%) – including printable text interfaces, direct screens with captions, photographs, and graphics for the communication partner [40, 150]. More abstract visual signal systems have been researched including LED lights and graphics [166]. Motion-based AAC is an emerging research area (N=11, 2%). For instance, the motion of robots to communicate [85] – including in LEGO adaptable forms for children [1] and co-designed novel sidekicks [180]. In addition, haptic feedback has been briefly explored for individuals with deaf-blindness [171]. Our dataset did not include AAC that uses taste or heat as a modality for communication.

4.1.2 Typical Features of High-tech AAC. In Table 2, the feature space of high-tech AAC is rich – here we coded for scalar attributes and the interface layouts of high-tech AAC. We found that accessibility researchers have prioritised developing high-tech AAC that is customisable (N=310, 55.2%) and automatic (N=262, 46.6%). Customisability has been honed as a significant factor for making high-tech AAC more usable and personalized thereby increasing adoption and acceptance of the high-tech AAC [34]. Automation has been a well-explored and key area for high-tech AAC – automation of keystrokes [61], predictive text, abbreviation expansion [158] and leveraging AI [22] has been researched to improve users' communication rates. Following these two subcodes, high-tech AAC has been developed to be expressive (N=110, 19.6%) for different genders [68], cultural groups [82], and age ranges [35]. To a lesser extent AAC has been developed to receive combinations of inputs (N=57, 10.1%) to improve usability. Research has considered making high-tech AAC more practical (N=45, 8%) – through making the

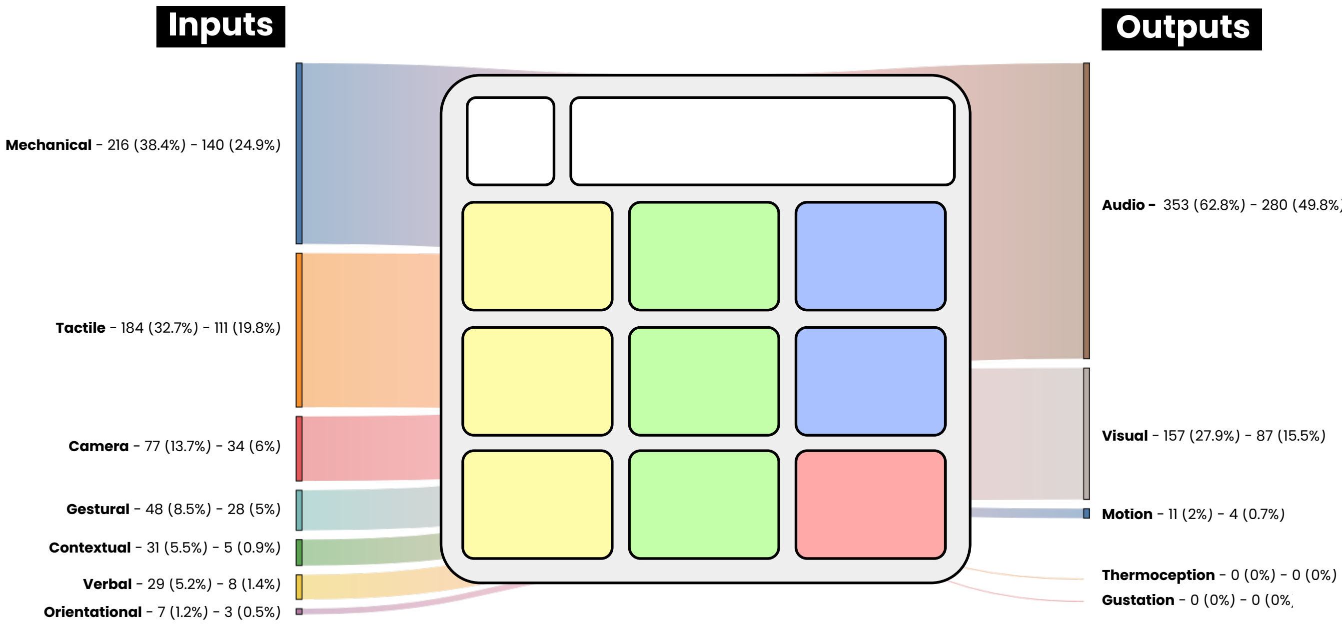

Figure 4: Sankey diagram proportionally representing inputs and outputs of AAC found in the review. The first number indicates the frequency, the second the number or instances this code was found without other inputs/outputs.

Table 2: Frequency of applied codes for high-tech AAC scalar attributes and high-tech AAC interface layouts mentioned in dataset.

Scalar attributes	Papers w/code	This code only	Interface layout	Papers w/code	This code only
Customizable	310 (55.2%)	81 (14.4%)	Text	322 (57.3%)	84 (14.9%)
Automatic	262 (46.6%)	39 (6.9%)	Symbols	223 (39.7%)	18 (3.2%)
Expressive	110 (19.6%)	8 (1.4%)	Grid format	157 (27.9%)	2 (0.4%)
Combined	57 (10.1%)	3 (0.5%)	Pictures/drawn	127 (22.6%)	8 (1.4%)
Practical	45 (8%)	4 (0.7%)	No layout	29 (5.2%)	29 (5.1%)
Adaptive	42 (7.5%)	3 (0.5%)	VSDs	29 (5.2%)	2 (0.4%)
Parallel	17 (3%)	0 (0%)	Video or animation	23 (4.1%)	4 (0.7%)
Morphable	14 (2.5%)	0 (0%)	Novel	5 (0.2%)	2 (0.4%)

device discreet, wearable, small and lightweight [193]. Accessibility researchers have considered leveraging AI systems to improve the adaptiveness (N=42, 7.5%) of the AAC system – to improve feature recognition i.e., eye gaze/landmark detection, to orient to the user over time [6] and for improving frequency prediction algorithms of vocabulary dependent on location and usage history [62].

A small amount of research has considered making high-tech AAC parallel (N=17, 3%) and morphable (N=14, 2.5%). Examples of parallel AAC includes a high-tech device that receives eye-gaze and simultaneous input suggestions from the communication partner to increase communication rates during exchanges [51]. Limited high-tech AAC is morphable thereby physically adaptive according to the consumer preferences or designed to run on different hardware and devices. Some examples, include do it yourself (DIY) AAC kits [71], Lego robots physically configurable by the child [2] and an AAC device that changes form factor by running on either a wrist wearable and head worn display [193]. In terms of interface, we find that most high-tech AAC interfaces use text (N=322, 57.3%) and symbols (N=223, 39.7%). Historically, grid formats (N=157, 27.9%) for AAC often with accompanying symbols have been popular [4]. To a lesser extent high-tech AAC has leveraged pictures or been drawn (N=127, 22.6%). Few papers had no or a limited interface meaning the AAC operated off sensors (N=29, 5.2%) [151]. A notably small number of papers (N=29, 5.2%) provided research of high-tech AAC with a visual scene display (VSD). Lastly, a small selection of papers (N=5, 0.2%) had entirely novel interfaces including LED morse code [78], augmented reality [94], and tactile surfaces [171].

4.1.3 Communication Supported by High-tech AAC. High-tech AAC is designed for *different* scenarios and contexts of usage (see Table 3) – here we code if papers *explicitly* mentioned contexts in which the device could be used. Significantly, devices have mainly

Table 3: Frequency of applied codes for scenarios of high-tech AAC usage mentioned within dataset.

Scenario	Papers w/code	This code only
Professionals	315 (56%)	155 (27.8%)
Family/friends	221 (39.3%)	56 (10%)
Strangers	65 (11.6%)	14 (2.5%)
Groups	39 (6.9%)	1 (0.2%)
Virtual	37 (6.6%)	21 (3.7%)
Fellow AAC users	11 (2%)	1 (0.2%)
Anyone	7 (1.2%)	5 (0.9%)
Unclear	22 (3.9%)	22 (3.9%)

been built for professional contexts typically with specialists, teachers or carers (N=315, 56%). Additionally, high-tech AAC has often been designed to be used with family and friends (N=221, 39.3%) at home or in social settings. A smaller number of papers (N=65, 11.6%) mentioned designing high-tech AAC for use with strangers or unfamiliar communication partners. In addition, an even smaller number of papers discussed high-tech AAC to be used with groups (N=39, 6.9%) and virtual communication (N=37, 6.6%). Group scenarios involve several people – making the communication environment pose potentially significantly more challenges for the high-tech AAC device [180]. Also high-tech AAC will need to facilitate user's self-expression and communication in virtual environments (N=37, 6.6%) – a small subset of papers has considered this for phone calls [50], videoconferencing [96], and online gaming [169]. Lastly, we find little high-tech AAC aware of supporting communication exchanges between fellow AAC users (2%) with the same or a different high-tech AAC device – yet it is potentially common for two high-tech AAC users to directly communicate with each other regularly e.g., within special needs schools [81, 140]. In Table 4, we find that most high-tech AAC is designed to augment and enrich verbal communication (N=519, 92.3%) – high-tech AAC to *just* support users non-verbal forms of communication is neglected in the literature (N=8, 1.4%) [52]. Furthermore, we find limited high-tech AAC devices operating at communication rates beyond interactive. Instead, linear is by far the most common communication model (N=491, 87.4%) – here using the device to provide feedback is restrained and the AAC user must take significant time to construct messages [11]. Interactive high-tech AAC devices (N=61, 10.9%) increase the communication rate by enabling the AAC user to offer feedback in a restrained manner. We find some high-tech AAC (N=8, 1.4%) could potentially offer pathways to transactional communication for its user. Here, high-tech AAC leverages snippets of discourse utilising advanced technologies to take in contextual information [63, 195] significantly diminishing the reciprocity gap between communicators [27].

4.2 The Incumbent Methodologies Used to Design and Study High-tech AAC

4.2.1 High-tech AAC Contribution Counts and Types. Depicted in Figure 5, paper counts for high-tech AAC has grown steadily over the period of 1978-2021 yet this growth surges with counts over 25 for each year since 2011. This replicates wider trends noting the increasing prominence of accessibility research [112]. Notable market available hardware innovations have also fed this growth. High-tech AAC devices have become *more* readily available with designers able to shift from dedicated hardware e.g., Dynavox DynaMyte 3100 (1999) to increasingly developing apps e.g., Proloquo2Go (2009) for accessible touch-screen devices such as smartphones e.g., iPhone (2007) and smart-tablets e.g., iPad (2010). Further analysing the input/output data over time in Table 5, we find trends have to a greater extent reciprocated evolution's in the market available hardware and a general increase over time[16]. Predictably, in terms of inputs camera (0% to 22.4%) and tactile touchscreen technology has increased with time (0% to 43.3%).

Whilst, mechanical inputs have steadily fallen over time (100% to 22.4%). In Table 6, we found the majority of high-tech AAC contributions were empirical (N=410, 73%) and artifact (N=224, 39.9%) contributions. The two contributions regularly occurred in conjunction (N=169, N=30.1%). Similarly, in the Mack et al. dataset these were both the two most popular contribution types [112]. Equally, the following four contribution types occurred comparatively less with Survey (N=60, 10.7%), methodological (N=43, 7.7%), theoretical and opinion (N=19, 3.4%) and Dataset (N=6, 1.1%). However, a notable difference with the Mack et al., was that literature survey contributions were much higher for high-tech AAC (+10.1%) and typically published within the AAC journal (N=31/60, 51.6%) – literature surveys are a regular practice to provide essential reflection on current medical practices [155].

4.2.2 Location of User Studies. Incorporating locations beyond the lab may enable accessibility researchers to have more users and test if high-tech AAC functions in settings where it will be used day-to-day. Our results noted in Table 7, quite closely replicate trends found in the Mack et al., research [112]. A substantial proportion of studies take place at home, residence or school (N=181, 43.6%) and near or in the researchers laboratory (N=178, 42.8%). High-tech AAC researchers have been successful at recruiting participants for studies that take place at home or schools – a place where participants are comfortable and visit frequently [55]. Furthermore, user studies in these locations may broaden participation amongst vulnerable groups e.g., testing high-tech AAC with children [55]. Lab studies are almost as popular, enabling the research team to carefully control the variables and environment for testing – supporting the collection of observation data [173]. Neutral locations (N=71, 17.1%) feature relatively prominently and are diverse such as: day programs [39], intervention camps [32], clinics, medical centres [163], fast food restaurants [44], extracurricular clubs and community centres [191]. Some of these locations have the advantage of testing the high-tech AAC in live, realistic and natural conditions that are hard to replicate within a lab. Often neutral locations are selected by the participants themselves due to personal preference [118]. Furthermore, these settings may imbue the user with confidence that the AAC can be used in a public location. Online and remote participation (N=50, 17.1%) has been used to

[16]We also note that this review was done approximately 1/5 the way through the 2020s, so accounts for a smaller number of papers. Extrapolating the number (i.e. multiplying the number of papers in the 2020s by 5), we get 335 papers – suggesting a continuing increase in the number of papers on AAC.

Table 4: Frequency of applied codes for high-tech AAC communication type and model within dataset.

Comms type	Papers w/code	This code only	Comms model	Papers w/code	This code only
Verbal	519 (92.3%)	517 (92%)	Linear	491 (87.4%)	430 (76.5%)
Non-verbal	8 (1.4%)	6 (1.1%)	Interactive	61 (10.9%)	0 (0%)
			Transactional	8 (1.4%)	0 (0%)

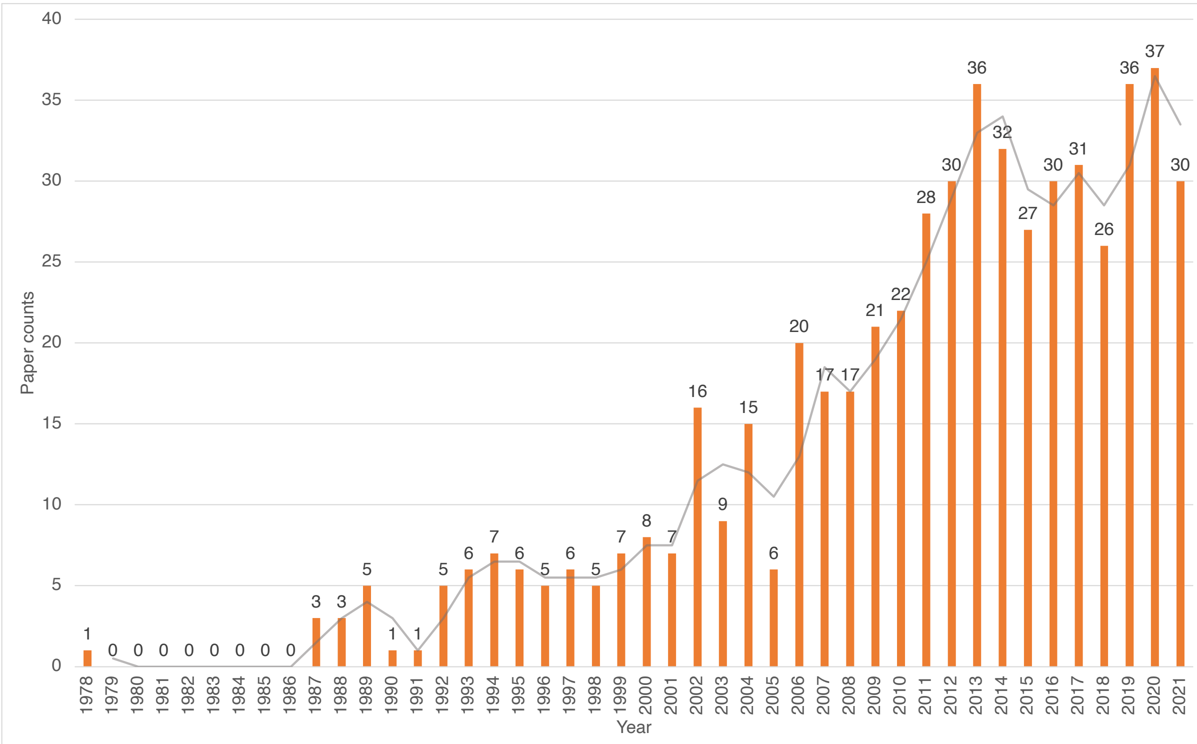

Figure 5: Frequency of 562 paper counts by year for high-tech AAC within dataset from 1978-2021.

test with large participant numbers and also may remove travel burdens for participants [168].

4.2.3 Methods in User Studies. Reflecting on the user-centred nature of high-tech AAC, overwhelmingly user studies are favoured (N=415, 73.8%) – despite the potential difficulties of obtaining participants with CCNs who often cannot easily provide verbal consent. In contrast, studies which do not incorporate user studies (N=147, 26.2%) involve artifacts with no user testing (N=57, 10.1%) survey (N=53, 9.4%), methodological (N=25, 4.4%), theoretical (N=15, 2.7%), empirical (N=7, 1.2%) and dataset (N=4, 0.7%) contributions. These studies without formal user testing – typically involve prototype development [177], exploratory studies [108] and analyses of user-studies conducted in other research [154]. Noted in Table 8, the dominant preference for studying high-tech AAC is controlled experiments (N=188, 45.3%) and usability testing (N=119, 28.7%). Interviews (N=67, 16.1%) rank to a lesser extent and typically involves interviewing speech and language therapists (SLTs) and family members due to the challenges of directly interviewing someone with CCNs [132]. Field studies (N=75, 18.1%) and case studies (N=48, 11.6%) also rank quite highly – researchers often try to learn of the success of deployment by observing in naturalistic settings high-tech AAC usage [67]. Lastly, we found no contributions using randomized control trials (N=0, 0%) (RCTs). Surveys and questionnaires (N=65, 15.7%) have been regularly deployed to assess over large groups of users and gain an understanding of potential patterns and commonalities [168]. Furthermore, surveys enable high-tech AAC users to communicate at there preferred rates without feeling pressure to provide feedback quickly [133] and AAC is a well established community with foundations/charities with extensive mailing lists [47, 121, 183]. Focus groups (N=21, 5.1%) and workshops (N=4, 1%) feature quite lowly – due to the complexities of gaining feedback from users with communication barriers [16, 90]. Comparing to the broader Mack et al. dataset [112], high-tech AAC research comparatively favours more case studies (+7.6%) and controlled experiments (+10.7%) at the expense of interviews (-26%), workshops (-17.4%) and usability testing (-13%).

4.2.4 Participatory Methods. Participatory design (PD) provides a method for involving users of technology direct in its design [57,

Table 5: Incremental 10 year binning of frequency of applied codes for input/output data of AAC over time. Percentage calculation involves dividing number of papers with code by paper count within period. Data is weighted towards AAC from the 2000s and 2010s, with a steady year-on-year increase over time. We see a gradual diffusion in output types, away from only mechanical to a more equal split of form factors. We see audio and visual dominating as outputs consistently over time.

Input	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**2020s**
Paper count	1	11	49	136	298	67
Verbal (%)	0	9.1	2	8.8	5	0
Camera (%)	0	0	0	7.4	17.5	22.4
Tactile (%)	0	0	0	27.9	39.3	43.3
Gestural (%)	0	18.2	2.1	6.6	9.7	10.5
Mechanical (%)	100	81.8	71.4	55.2	27.2	22.4
Orientational (%)	0	0	0	0	1.7	3
Contextual (%)	0	9.1	2.1	4.4	6	7.5
Output	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**2020s**
Audio (%)	0	45.5	65.3	71.3	59.1	64.2
Visual (%)	100	45.5	28.6	22.8	28.9	29.9
Motion (%)	0	0	0	0	2.4	6
Gustation (%)	0	0	0	0	0	0
Thermoception (%)	0	0	0	0	0	0

Table 6: Frequency of applied codes for high-tech contribution types within dataset versus Mack et al. accessibility data [112].

Contribution types	**Papers w/code**	**% diff.**	**This code only**	**% diff.**
Empirical	410 (73%)	+12.7	226 (40.2%)	+6.4
Artifact	224 (39.9%)	-15.6	52 (9.2%)	-26.8
Survey	60 (10.7%)	+10.1	51 (9.1%)	+9.1
Methodological	43 (7.7%)	+4.5	18 (3.2%)	+2.8
Theoretical and opinion	19 (3.4%)	-5.3	12 (2.1%)	+0.9
Dataset	6 (1.1%)	-0.3	6 (1.1%)	+0.7

Table 7: Frequency of applied codes for location for 415 user study papers within dataset versus Mack et al. accessibility data [112].

Study location	**Papers w/code**	**% diff.**	**This code only**	**% diff.**
Home, residence or school	181 (43.6%)	+14.7	139 (33.5%)	+15.7
Near/at researchers lab	178 (42.9%)	+15.6	145 (34.9%)	+15.4
Neutral location	71 (17.1%)	+10.4	37 (8.9%)	+5.8
Online/remote	50 (12%)	-8.5	34 (8.2%)	-1.9

112]. However, PD methods have not been widely adopted in high-tech AAC user-study papers (N=20, 4.8%) – lower than the Mack et al. dataset (-5.5%). Indeed, for users with CCNs – traditional PD methods are *more* inaccessible compared to other communities and groups [28, 136]. PD is cognitively demanding and requires for people with CCNs to have high levels of speech and language proficiency [136, 194]. Prior research has outlined challenges in engaging populations with autism [57], aphasia [28, 90], Parkinson's/dementia [26] and IDD [136] in PD. Researchers have developed solutions to mitigate against this through proxies [28] – e.g using SLTs for the PD of high-tech AAC. Other studies that did not use co-design engaged in other rich design activities such as user-centred design [186], intervention programs [187], use of probes [129] and academic workshops [195].

4.2.5 Category of Devices. Figure 6, shows that research has regularly provided interventions using expensive standalone commercial high-tech AAC devices including DynaVox models (N=63) e.g., the Dynavox 3100 (N=9) and their eyetracking technologies the Tobii models e.g., Tobii T60 (N=5), Tobii X120 (N=1). Other standalone high-tech AAC devices used in research includes the Lightwriter (N=14), Pathfinder (N=14) and Liberator (N=13). Yet, recently research has increased with downloadable software e.g, EZ keys (N=6), SentenceShaper (N=7) or apps e.g., Proloquo2Go (N=16), Go Talk

Table 8: Frequency of applied codes for methods for 415 user study papers within dataset versus Mack et al. accessibility data [112].

Method	Papers w/code	% diff.	This code only	% diff.
Controlled experiment	188 (45.3%)	+10.7	128 (30.8%)	+19.3
Usability testing	119 (28.7%)	-13	45 (10.8%)	+1.2
Field studies	75 (18.1%)	+0.3	25 (6%)	+1.4
Interviews	67 (16.1%)	-26	18 (4.3%)	-1.4
Surveys and questionnaires	65 (15.7%)	-9.9	23 (5.5%)	+4.2
Case studies	48 (11.6%)	+7.6	32 (7.7%)	+7.5
Focus groups	21 (5.1%)	-0.8	7 (1.7%)	+0.9
Workshops	4 (1%)	-17.4	1 (0.2%)	-2.9
Other	2 (0.5%)	-15.6	2 (0.5%)	-0.3
Randomized control trials	0	n/a	0 (0%)	n/a

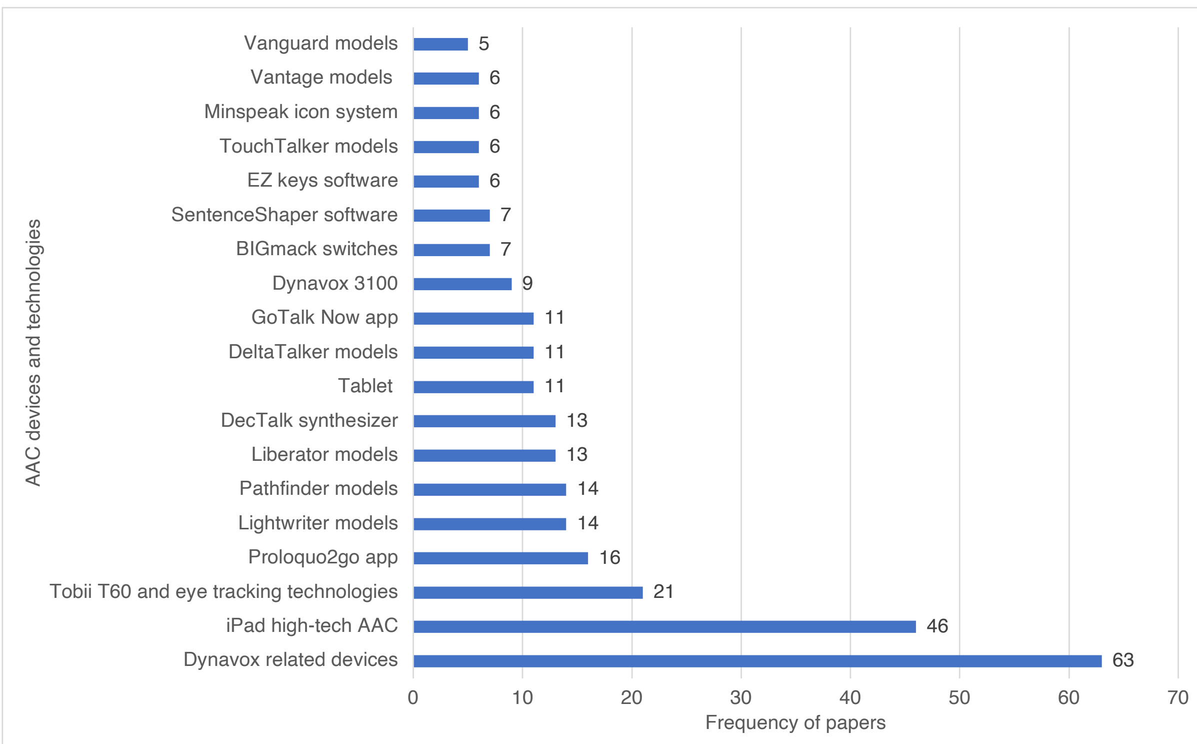

Figure 6: Inventory of 19 key devices and technologies with a frequency of above 5 papers within dataset.

Now (N=11), which converts laptops, smartphones, iPad's (N=46) or tablets (N=11) into a high-tech AAC device has grown in prominence. Elsewhere, we find a slight preference towards testing with commercial (N=227, 54.7%) versus non-commercial (N=188, 45.3%) high-tech AAC within user-study papers. Indeed, for SLTs and non-computer science research groups it is often easier to program and customise pre-existing available commercial high-tech AAC devices than develop new non-commercial high-tech AAC. Other advantage of commercial high-tech AAC is that they are a more reliable intervention as the device is maintained by an external corporation [4]. Non-commercial offerings involve the research team actively building and developing new high-tech AAC solutions for the end users within the study. Advantages of the non-commercial solutions is that the high-tech AAC is often free to its user, and does not involve external purchase, subscription and maintenance fees [186].

4.3 Communities of Focus and Participants for High-tech AAC Research

4.3.1 The Communities of Focus. Shown in Table 9, high-tech AAC research has largely focused on users categorised as Other (N=219, 39%) and motor impairments (N=182, N=32.4%). Users categorised

Table 9: Frequency of applied codes for community of focus within dataset versus Mack et al. accessibility data [112].

Method	Papers w/code	% diff.	This code only	% diff.
Other	219 (39%)	+29.9	209 (37.2%)	+33.2
Motor impairments	182 (32.4%)	+18.2	146 (26%)	+14.3
Other cognitive	74 (13.2%)	+4.1	59 (10.5%)	+4.8
Autism	71 (12.6%)	+6.5	46 (8.2%)	+4
IDD	67 (11.9%)	+9.1	29 (5.2%)	+3.6
DHH	14 (2.5%)	-8.8	5 (0.9%)	-7.6
BVI	11 (2%)	-41.5	2 (0.4%)	-40.2
Older adults	4 (0.7%)	-8.2	0 (0%)	-5.7
General disability	3 (0.5%)	-8.6	1 (0.2%)	-5.9

as "Other" do not belong to a specific community of focus and the research is to contributing to a broad community of high-tech AAC users e.g., "children" or "AAC users" – this is despite each disabled group having very specific requirements[17]. Motor impairments have also received a significant research contribution (N=182, 32.4%). In particular, disabilities such as cerebral palsy (N=107, 19.1%) and ALS (N=20, 3.6%) have been a specific focus for the motor-impairment high-tech AAC research. Groups that have received less research include cognitive impairments (N=74, 13.2%), autism (N=71, 12.6%) and IDD (N=67, 11.9%). Within other cognitive impairments, the dominant contribution has been towards people living with aphasia (N=47, 8.4%) and people with TBIs (N=10, 1.8%). Many of the autism and IDD contributions have built high-tech AAC with child and adolescent users e.g., [55]. Groups with little research include BVI (N=11, 2%), DHH (N=14, 2.5%), Older adults (N=4, 0.7%) and General disabilities (N=3, 0.5%) – these are not mainstream users of high-tech AAC with CCNs. Our data versus the Mack et al. dataset for accessibility research reveals some differences [112]. In broader accessibility research BVI is the dominant focus (-41.5%), whilst in high-tech AAC it is Other (+29.9%) and motor impairments (+18.2%). Also, Autism (+6.5%), IDD (+9.1%) and Other cognitive impairments (+4.1%) received a slightly higher proportion of contributions within our dataset. However, DHH (-8.8%), Older adults (-8.2%) and General disability (-8.6%) received a slightly lower contribution within our dataset.

4.3.2 Study Participants. Table 10 shows the participant data for user studies. The majority of studies include people with disabilities (N=305, 73.5%) albeit in these studies the median participant counts are predominantly low (N=5) and imbalanced with a high standard deviation (SD) and range. Equally, fewer papers include people with just disabilities only (N=178, 42.9%). A proportion of the papers include caregivers (N=75, 18.1%) and specialists (N=62, 14.9%) particularly often to complement other users involved in the user-study[18]. A sizeable proportion of the user studies include people without disabilities (N=130, 31.3%) with even N=82 papers (19.8%) only with people without disabilities. For studies including people without disabilities we find participant counts are much higher with a median of N=18. Due to the difficulties designing for users with CCNs – proxies are often favoured [28]. Indeed, it is even quite common for papers to test with proxies to gain initial data on high-tech AAC before considering a disabled group of users [28]. Albeit, sometimes it makes legitimate sense to use participants without disabilities because the research is examining *perspectives* on high-tech AAC – monitoring its social acceptance amongst peers e.g., [101].

A significant proportion of high-tech AAC user-study papers include specialists (14.9%) and caregivers (18.1%). Additionally, in these studies, the median participant count positively increases for specialists (N=9.5) and caregivers (N=8.5). Indeed, this is to be expected as people with CCNs in user-studies sometimes require caregivers and specialists to assist with communicating and expressing themselves [136]. Equally, these groups can provide key insights and feedback on the high-tech AAC within the user-study [28]. Comparing these findings versus the wider Mack et al. research we find a lower number of user studies coded with people with disabilities (-11.2%) and higher number of user studies using people without disabilities (+8.2%). In addition, we find a marginally lower number of papers with specialists (-2.1%) but much higher usage of caregivers (+8.7%). In terms of community of focus, participant counts are median highest for the non-specific category of Other (N=16). However, median participant counts are lower for Motor impairments (N=6) and Other cognitive (N=6), yet participant counts are *very* low for high-tech AAC user-study papers involving people with IDD (N=5) and Autism (N=4)[19]. Overall, the low median participant counts, high ranges and standard deviations reflect the methods favoured in high-tech AAC research – very large surveys versus interventions with *just* one or a small group of users.

4.3.3 Usage of Proxies and Ability-based Comparisons. From our 415 user-study papers, we identified 86 papers where proxies were used (N=86, 20.7%) – higher than the Mack et al. dataset (+12.7%). To a certain degree, this trend was expected as proxies are often used to circumvent communication barriers [28]. However many of the proxy papers (34.9%, N=30/86) were for motor impairments, which compromises the validity of findings as it is difficult for a proxy user to accurately replicate the role of a motor impaired user [113]. Sometimes a member of the research team has acted

[17] E.g., The high-tech AAC requirements of a user living with aphasia is very different to a user living with cerebral palsy.

[18] Indeed, only N=15 papers are coded with just specialists and N=6 coded with just caregivers.

[19] Typically, these studies can often include vulnerable children users of high-tech AAC resulting in a lower-participant count

Table 10: Frequency of applied codes for study participants within 415 user study papers versus Mack et al. accessibility data [112].

Participant group	Papers w/code	% diff.	This code only	% diff.
People with disabilities	305 (73.5%)	-11.2	178 (42.9%)	-2
People without disabilities	130 (31.3%)	+8.2	82 (19.8%)	+18.8
Caregivers	75 (18.1%)	+8.7	6 (1.4%)	+0.6
Specialists	62 (14.9%)	-2.1	15 (3.6%)	+1.7

Table 11: Quantitative analysis of participant counts for 415 user-study papers by community of focus and participant groups.

Group	Median	IQR	SD	Mean	Range	Total papers
Older	78	79	80.3	94.7	24–182	3
People without disabilities	18	20.25	84.6	32.7	1–893	130
Other	16	27.5	1188.5	146.1	1–12,776	121
Specialists	9.5	18.75	63.8	31.6	1–320	62
DHH	9.5	37.8	3678.5	1085.6	1–12,776	12
Caregivers	8.5	26	87.2	37.6	1–624	75
General	8	4.5	4.7	6.3	1–10	3
All user-studies	7	17	635.1	54.2	1–12,776	415
Other cognitive	6	9.5	12.4	10.5	1–75	63
Motor impairments	6	12	1024.3	105.4	1–12,776	158
People with disabilities	5	11	735.7	62.5	1–12,776	305
IDD	5	8	1719.9	243.9	1–12,776	55
Autism	4	8.75	1735.8	248	1–12,776	54
BVI	2	20	22	14.9	1–60	8

as a proxy high-tech AAC user to obtain social perspectives from peers on the device and its user [176] and proxies are used for initial pilot testing of devices to quickly determine the effectiveness and usability of the device [197]. We identified just 25 cases of ability based comparisons (N=25, 6%) in which disabled and non-disabled participants were compared in the user-study papers – sometimes this is to have able participants act as the control group for determining if the high-tech AAC SGD offers the same intelligibility as natural human vocals [127] and whether the communication rate is equivalent [88]. Additionally, testing has been performed in dyads to determine cross-task performance [159]. Comparing to the Mack et al., ability based comparisons are used less frequently (-7.6%) within our dataset [112].

5 DISCUSSION

Despite four decades of research, abandonment of high-tech AAC devices and interventions continues [140, 185]. Therefore, this first SR and taxonomy of ACM high-tech AAC research serves as a reflection for more successful future high-tech AAC development and intervention outcomes. Based on our taxonomy and results, we formulate directions for further research in high-tech AAC and interventions in light of our three research questions: 1.2 to 1.2.

5.1 Expanding the Characteristics of High-tech AAC Devices and Interventions

Our first research question – presents *what* is the pre-existing taxonomy and dominant characteristics of high-tech AAC. From our examination and codification of the literature we find that mechanical (38.4%) was the dominant input modality for standalone high-tech AAC devices before a surge in tactile (32.7%) inputs with the decentralisation of high-tech AAC through capacitive touchscreens (e.g., smartphones, tablets) and easily downloadable apps (e.g. through app stores). However, audio (62.8%) and visual (27.9%) have remained the most well explored output modalities. In response to these findings, high-tech AAC designers should more systematically explore the input/output interaction possibilities of using high-tech AAC. For example, with regards to inputs: camera, gestural, verbal and contextual inputs serve as a still largely unexplored input modalities (5.2% to 13.7%), which we believe hold much promise for future high-tech AAC. For instance, Fiannaca et al., increased gaze-based and eye-tracking communication rates leveraging contextual inputs with the AACrobat [51]. Additionally, Wisenburn et al., used verbal inputs from partner speech recognition providing contextually relevant utterances and increased communication rates [195]. Lastly, with regards to gestural interaction Ascari et al., explored non-invasive personalised gestural interaction for the purposes of communication [7] whilst BCI-AAC remains an emerging research area, which enables practitioners to entirely bypass users motor system – albeit the successful deployment and calibration of BCIs is currently challenging [119, 148, 149].

High-tech AAC devices that have leveraged novel input characteristics have offered promising results for their user groups, for instance using camera input for eye-tracking [97], storytelling [3] and understanding the environment [141]. Harnessing pre-existing interdisciplinary AI research such as natural language processing (NLP) [73] or smart environments [23, 36, 64], might support the development of contextual and verbal inputs for high-tech AAC to improve communication rates, enable easier interactions, more agency and autonomy. Complementary research on outputs, finds that high-tech AAC typically outputs audio (62.8%) and visual (27.9%) channels to communicate – future work might explore the feasibility of the motion (2%) and even thermoception (0%) as outputs. Indeed, these *more* subtle and less information dense channels can still be leveraged to support communication and engaging human to human interaction, particularly non-verbal communication (c.f. "sidekicks" [179] and physical expressive objects [180]).

With respect to common scalar attributes and interface layouts of high-tech AAC, we find that AAC is often customisable (55.2%) and offers automation (46.6%) typically for prediction to foster increased communication rates [74]. Whilst high-tech AAC layouts often use text (57.3%), symbols (39.7%), grids (27.9%) and pictures (22.6%) – for instance the DynaVox 3100 serves as a typical grid, symbol and text based interface [4]. To better expand these characteristics, future AAC that *just* offers customisation and automation is likely not enough. Indeed, too often using high-tech AAC does not *feel* natural but restrained for the end user's autonomy resulting in abandonment [81, 140] – the voice of the device does not reflect their personhood [117], the device is impractical to carry around day-today [11], indiscreet limiting social acceptance [145], difficult to use with few modes of input [20] and not adaptive to the constantly evolving communication abilities of the user [20, 80]. Additionally, future AAC research could explore more VSDs, video and animation – these are under researched interfaces with the ability to convey meaning [83]. Importantly, high-tech AAC designers must be aware that text-based interfaces are challenging for some groups – e.g., people with aphasia [189].

Turning to scenarios of usage, communication types and models – we find that high-tech AAC devices are typically designed to be used with professionals (56%) and families/friends (39.3%) supporting verbal communication (92.3%). However, high-tech AAC designers must be aware that users with CCNs often have larger social groups than anticipated [180], users also require the ability to use their high-tech AAC to communicate virtually (6.6%) on social media [34, 123] or as widely appreciated during the pandemic, on videoconferencing software [96, 137, 180]. Little high-tech AAC is designed to function in group settings (6.9%), particularly if the communication partner is a fellow AAC user (2%) with the same or a similar high-tech AAC device – research has shown that in this case breakdowns are common unless both users have analogous vocabulary libraries pre-installed prior to the exchange [20, 81]. In addition, there has been an under representation of high-tech AAC that empowers the users non-verbal communication (1.4%) – this compounds into most high-tech AAC offering linear communication interactions (87.4%) [180]. Indeed, high-tech AAC must show an appreciation of the users pre-existing communication abilities to increase communication rates beyond linear – encouraging embodied forms of communication and re-framing high-tech AAC as an accepted interdependent assistive technology [15, 81]. Too often, high-tech AAC restrains communication by acting as a physical independent barrier – restraining the user from freely employing there own unique communication skills including non-verbal signals to provide feedback more quickly [15, 52, 81].

5.2 Reassessment of Incumbent Research Contributions and Methodologies in High-tech AAC Research and Interventions

The second research question of this paper focused on what methods are used to contribute towards high-tech AAC research and interventions. Versus other contributions, dataset contributions (1.1%) are comparatively under-explored, thus high-tech AAC research could *certainly* have more contributions focused on AI and ML datasets. As proposed by Mack et al. and Kane et al., looking to the future, AI and ML datasets should certainly be rooted in accessibility research [112] and equally have the potential to greatly enrich the effectiveness of high-tech AAC research and interventions [92, 140]. Already, work at ASSETS'21 by Theodorou et al. [172] explores the concept of a "Disability-First" dataset, which supports an accessible method for visually impaired users to create their own datasets for personal object recognition. Furthermore, as rightly noted by Park et al., there is a definitive lack of data from disabled populations and consequently they have provided a robust set of design guidelines for developers looking to gather data from disabled populations [147]. Indeed, the properly considered deployment of AI within high-tech AAC might support quicker, empathetic and more seamless communication opportunities for people living with CCNs [140]. For instance, Vertanen et al., successfully deployed crowd-sourced data-sets to offer improved word prediction and better high-tech AAC communication rates – yet critically, the underlying data did *not* originate specifically from AAC users and disabled communities [184].

User-study papers (73%) compromise a sizable proportion of our dataset and we believe this must continue and even increase for successful high-tech AAC outcomes [140]. The location of user studies is significant for high-tech AAC – researchers have successfully tested widely in: residences (43.6%), labs (42.8%), neutral (17.1%) and even remote (12%) locations. Nonetheless, researchers must look to test high-tech AAC performance in the *very* conditions where it will be deployed. Key reasons preventing high-tech AAC adoption, include that the devices promise an unrealistic "magic wand" [20], failing to adapt to the contextual environmental challenges (e.g., noisy environments) [96, 117] or consider peer perceptions of the high-tech AAC device [5] – the potential accompanying stigmas and its effect in conversational power dynamics [15, 101]. Indeed, the high-tech AAC device should be shaped by its user and context of usage [20] – high-tech AAC performance cannot be assumed on the basis of unnatural controlled conditions rather than the actual contexts of daily usage [140]. With regards to high-tech AAC research methods, we found no cases of randomized control trials (RCTs) (N=0, 0%) within our dataset. Indeed in 2018, Kent-Walsh et al. report that no RCTs have been published in the AAC journal [93]. However, further searching outside of the realm of this SR within the medical literature[20] we do find some RCTs with AAC e.g., [79, 134]. Furthermore, Todman et al. have strongly advocated for their usage

[20]Beyond the scope of our investigation, RCTs with AAC were found via medical literature databases i.e., https://pubmed.ncbi.nlm.nih.gov/ and Google Scholar.

as AAC devices are categorised as medical equipment requiring random assignment procedures for treatment efficacy [175]. Therefore, we suggest further RCTs to mitigate against bias and the ensure clinical efficacy of high-tech AAC interventions [176].

Elsewhere, usability testing (28.7%), interviews (16.1%), workshops (1%) and PD methods (4.8%) all rank lower than the Mack et al. dataset for the general accessibility community. Consequently, we find a smaller use of methods in which AAC users with CCNs are directly engaged and the development process is cooperative e.g., [23, 90]. We accept that it is difficult to recruit, engage in interviews, participatory design, usability testing [16] and workshops [57] with users that have severe CCNs, struggle to communicate independently [90] and provide consent [28, 136]. Nonetheless, we echo Mankoff et al. [114] – we must, as a community, actively strive to include end users within the design and development process of AAC. Researchers have, in summary, not received enough feedback[21] from empowered end users during the development process. Future research should build upon prior PD which has focused on motor-impairments [41], autism [57, 167], dementia [109], aphasia [60, 138, 194] and older individuals [110]. Further participatory designed high-tech AAC solutions for people with CCNs could result in better outcomes and more long-term adoption [136]. Indeed, examples of PD found within our high-tech AAC dataset include Kane et al.'s TalkAbout - a context-aware, adaptive AAC system co-designed in collaboration with 5 adults with aphasia [90] and de Faria Borges et al.'s PD4CAT customized communication device developed in collaboration with a child with cerebral palsy [41].

5.3 Engaging with Communities and Greater Representation in High-tech AAC Research and Interventions

For the third research question and understanding *who* does high-tech AAC research focus upon, we get very different results from the Mack et al. research. In contrast, within our dataset Other (39%) and Motor impairments (32.4%) feature prominently versus the Mack et al. yet comparatively BVI takes up a *much* smaller minority of research (-41.1%). Directly commenting on these results, pre-existing high-tech AAC research has perhaps lacked specificity regarding its targeted community of focus as the majority of contributions within our dataset is towards Other [112]. Investigating further, we find that the Other community of focus frequently in papers is represented as diluted communities such as "AAC users" e.g., [56] or "Children" e.g., [144]. This lack of specificity has perhaps resulted in high-tech AAC that lacks focus or curated design for specific target groups, disabilities, communities and their unique set of needs [112]. Therefore, a clear direction for research is that we implore future high-tech AAC development to be directly contributing towards a *specific* community of focus with CCNs. Elsewhere, we find that Other cognitive (13.2%), ASD (12.6%) and IDD (11.9%) could receive more high-tech AAC contributions and are under represented versus Motor impairments (32.4%) – indeed Other cognitive [146], Autism [37] and IDD [115] are prominent communities within society. Lastly, Older adults have a very small contribution (0.7%) – nonetheless high-tech AAC could feasibly contribute towards people living with dementia and other CCNs that will become more prominent from an ageing global population [116].

With regards to participant groups, people with disabilities feature most prominently (73.5%), followed by people without disabilities (31.3%). Although our high-tech AAC dataset has less people with disabilities (-11.2%) and more people without (+8.2%) versus the Mack et al. – we believe that this is because our dataset occurs over a broader period (1978-2021) meaning that this change is perhaps symptomatic of evolving standards of practice for accessibility research in particular a focus on increased engagement with participants with disabilities as a consequence of the social model of disability [45]. Therefore, we echo Mack et al.'s encouragement of more direct engagement with people with disabilities [112]. Furthermore, high-tech AAC research has shown a propensity to engage with caregivers (18.1%), specialists (14.9%) and peers – in the right circumstances this should be encouraged. Indeed, caregivers, specialists (i.e., SLTs) and peers can often work as good communication partners in user studies with people with CCNs – supporting the high-tech AAC users' expression when engaging with the study [29] or for dyads [103]. Equally, if the study involves children, parents or guardians they can also help support the child with CCNs reflection and potentially provide feedback on the underlying effectiveness of the intervention [43]. Indeed, Delarosa et al., rightly note that the successful integration of a high-tech AAC system requires strong commitment from parents and other family members [43].

Non-disabled participants are regularly used within our dataset (31.3%), typically for either proxy usage (20.7%) or ability-based comparisons (6%). Despite difficulties designing and recruiting participants with CCNs [160], we advocate not using *just* proxies as Mack et al., note these high-tech AAC user studies run the risk of reinforcing *normalist* beliefs [112]. Furthermore, proxy users can often *not* accurately replicate a disabled user for testing the usability of a high-tech AAC device – particularly for users with motor-impairments [113]. Instead, proxies can be used jointly to perform initial testing [28], triangulate findings [58] and perhaps learn of the differences in social perceptions versus a disabled user with high-tech AAC [13]. Although ill-frequent within our dataset, ability-based comparisons are an imperfect heuristic for determining the performance of a high-tech AAC device – other qualitative findings concerning preference and satisfaction from disabled high-tech AAC users are more useful for determining if an intervention is successful [11, 87]. Indeed, even if the high-tech AAC successfully offers pathways for communication that is not *definitively* a pre-requisite for long-term adoption [20].

6 LIMITATIONS

As in all SRs, we had to limit its scope. Despite a robust PRISMA guided methodology, with snowballing, our approach would have not covered all AAC papers. Indeed we only used two scientific databases: the ACM DL and Scopus for constructing our SR dataset - there are other sources (e.g., IEEE, Elsevier, Thompson Reuters etc.) which will likely reveal more papers on the topic of high-tech AAC. Additionally, for manual coding of such a large dataset there are consequently areas of potential inconsistency, subjectivity

[21] Bircanin et al., have even suggested the formation of AAC *publics* to promote greater discourse on high-tech AAC to ensure more empowering high-tech AAC solutions are innovated [20].

and errors. Consequently, some researchers have argued in favour of using quantitative and automated analyses to mitigate against this concern [49, 69, 102, 104]. Our comparison of findings with the Mack et al. [112] dataset has limitations – we are a different research team and therefore have introduced subjective biases into our review and our dataset covers a wider breadth of literature. Indeed, future systematic reviews of AAC could look to be more focused – for instance, explicitly focus on commercial devices or AAC developed within a smaller period of inclusion. Much like other research [31, 112], we also encountered highly varied language use across papers, which impacted our classification of codes.

7 CONCLUSION

AAC is an essential support for many, yet is under-adopted and frequently abandoned. To provide deeper insight and directions for future research, we provide a taxonomic overview of the current state of high-tech AAC devices, the methodologies, contributions and communities of focus – compiling a paper count and inventory of the key devices used. Our results suggest three future research directions. Firstly, more research is needed to explore high-tech AAC inputs/outputs, the role of high-tech AAC in supporting non-verbal communication, high-tech AAC communication with groups, fellow AAC users and virtual scenarios. Secondly, in terms of specifically methods, future high-tech AAC research could use PD methods and RCTs. Thirdly and lastly, with respect to communities of focus limited high-tech AAC research focuses on Other Cognitive, Autism and IDD with low median participant counts for studies incorporating people with disabilities (N=5). We hope that our contribution will foster new and more optimally directed AAC research, towards promulgating greater adoption and more successful long-term intervention outcomes.

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