Int. J. Human–Computer Studies 177 (2023) 103078

Contents lists available at ScienceDirect

International Journal of Human - Computer Studies

journal homepage: www.elsevier.com/locate/ijhcs

Seeking information about assistive technology: Exploring current practices, challenges, and the need for smarter systems

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ARTICLE INFO

Keywords:
Information systems
World Wide Web
Web searching and information discovery

ABSTRACT

Ninety percent of the 1.2 billion people who need assistive technology (AT) do not have access. Information seeking practices directly impact the ability of AT producers, procurers, and providers (AT professionals) to match a user's needs with appropriate AT, yet the AT marketplace is interdisciplinary and fragmented, complicating information seeking. We explored common limitations experienced by AT professionals when searching information to develop solutions for a diversity of users with multi-faceted needs. Through Template Analysis of 22 expert interviews, we find current search engines do not yield the necessary information, or appropriately tailor search results, impacting individuals' awareness of products and subsequently their availability and the overall effectiveness of AT provision. We present value-based design implications to improve functionality of future AT-information seeking platforms, through incorporating smarter systems to support decision-making and need-matching whilst ensuring ethical standards for disability fairness remain.

1. Introduction

Assistive technology (AT), for example wheelchairs, hearing aids and communication or memory aids, enable people to maintain and enhance their quality of life, yet amongst those who need AT globally, 90% do not have access (World Health Organization, 2018). A core role of healthcare practitioners, including occupational therapists, audiologists, and prosthetists, is to help select and adapt an assistive product to the users' abilities and then ensure the user is fully trained in use (Hatzidimitriadou et al., 2019). Therefore, knowing what products exist or have become obsolete is of great importance. However, global AT marketplaces are diverse and continuously evolving, characterized by innovation that disrupts existing provision systems (Albala et al., 2021; Savage et al., 2019). Even in high-income countries or socialised healthcare systems, AT is often incompletely covered, and many informal private markets exist to fill these gaps. These markets are further expanded by an increasing number of do-it-yourself (DIY) AT design projects (e.g. (Hamidi et al., 2014; Hurst and Kane, 2013; Hurst and Tobias, 2011; Kuznetsov and Paulos, 2010; Meissner et al., 2017) which create open-source products. A diverse marketplace is a good thing, but it quickly becomes difficult for stretched healthcare professionals to keep track of and also poses a problem for direct-user purchases. These barriers contribute to high abandonment rates – up to 75% for hearing aids (Scherer, 1996) and more widely 35% of products are accepted to be abandoned by users (Dawe, 2006) because the product doesn't meet user needs (McCormack and Fortnum, 2013; Phillips and Zhao, 2010). Our paper contributes a new dimension to the HCI accessibility and assistive technology discourse. We explore information seeking, specifically, how we can better get information on the rapidly developing AT marketplaces to the people who make decisions affecting AT provision.

Effective information seeking, both for population- and individual-level decision making, is essential to expanding global access to all types of AT, yet information pathways tend to be highly fragmented (Andrich et al., 2019). Governments have historically not invested in the AT sector because most are without coherent and cohesive local data and a robust analysis approach to make decisions on the efficient allocation of assistive products and services (Savage et al., 2019). For designers and producers, a lack of AT demand information limits market entry options, particularly into under-developed markets such as low/middle-income countries (LMICs) where AT provision is often more limited and unmet need more prevalent. Consequently, this lack of presence prevents AT producers from developing a stronger

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https://doi.org/10.1016/j.ijhcs.2023.103078
Received 15 February 2022; Received in revised form 18 April 2023; Accepted 16 May 2023
Available online 18 May 2023

understanding of market demand and securing funding, especially in emerging markets (ATscale, 2019a, 2019b). Research in related fields has demonstrated how challenging it can be for individual providers, carers, or people with chronic conditions to seek relevant information to match specific needs to available products and services (Burgess et al., 2019; Singh et al., 2019). In the AT sector, limited information available to AT professionals can cause a bottleneck for access to these products, and this significant barrier needs to be addressed.

In response to this barrier, several initiatives have aimed to increase information-sharing between the diverse stakeholder groups of users and professionals. These initiatives include accessible HCI-based solutions and smart systems like AT service mapping applications (Visagie et al., 2019), centralised information-sharing platforms (Andrich et al., 2019; Lee et al., 2007), and recommender systems (Atvisor, 2021; Heumader et al., 2022) that in part address the complex challenge of informing stakeholders in a dynamic, international market. Additionally, smart systems present a unique opportunity to capture information from a wider variety of sources and provide tailored information to an inclusive audience (Chen et al., 2020), which may be especially useful for this diverse market. However, these systems alone do not fully address these barriers, often focusing on specific types of AT, functional domains, geographic regions, or providing incomplete/outdated information. Further investigation is also needed to discover specific challenges experienced when information seeking and attitudes towards smart systems amongst AT professionals, to design a system that would meet their needs and standards.

The Disability Interactions (DIX) Manifesto argues the HCI community is best placed to lead a new strategy to overcoming disability exclusion (Holloway, 2019). Having a fully inclusive society for all disabled people was proposed as a wicked problem, this can be seen, for example, in the difficulties of making a computing conference accessible (Mankoff, 2016). In the later book (Holloway and Barbareschi, 2021) which expanded on the concept of disability interactions, five DIX principles are established: 1) co-creation is core, but this must move beyond end users to for example procurers or the technology, 2) Radically different interactions can be expected and designed for with breakthrough technologies; 3) technologies must be open and scalable to ensure business models can be developed alongside the core technical advances; 4) to achieve this applied and basic science must be combined as was proposed by Shneiderman (Shneiderman, 2016) HCI is best placed to demonstrate the value and usefulness of technology to help solutions go from the lab to society. DIX has been used to explore how HCI can combat inequality in HCI (Barbareschi et al., 2021) and the social infrastructure of mobile phone use in low resource settings (Barbareschi et al., 2020). DIX principles can also be seen in emergent conversations around local production and sustainability (Holloway et al., 2020; Oldfrey et al., 2021).

Here, we use this value-based approach to focus on the challenge of information seeking as a barrier to AT access. In the AT sector, a unique challenge is the need for information to be relevant to a broad range of stakeholders (Savage et al., 2019); at one end, this includes the emerging DIY-AT group (Meissner et al., 2017), at another, governments and institutions (Allen et al., 2019), and in the middle, AT users, manufacturers, and providers (Hatzidimitriadou et al., 2019). Yet all stakeholders have primary experience seeking AT information and therefore represent an advantageous focus group for study. To scope the potential role for AI to address barriers to AT information seeking, these barriers must first be identified and concerns about incorporating AI features must be understood amongst this group. To this end, we conducted an interview study and Template Analysis with 22 AT professionals to identify common, persisting limitations of AT information seeking experienced by this group and value-based design implications for incorporating AI in HCI solutions that support disability inclusion.

2. Related work

In this section, we briefly discuss how HCI has shaped the design and provision of assistive technology, review prior work on interactive information seeking systems and practice, and finally synthesize studies about AT information sharing.

2.1. Assistive technology in HCI

AT has been increasingly explored in HCI as the research areas' overlap and capacity to develop one another expand (Liffick, 2016). Approaches are diverse; HCI researchers have developed AT design frameworks (e.g. Ability-based design (Wobbrock et al., 2011)), explored tensions between clinicians and makers (Hofmann et al., 2016), and researched the rise of accessible mobile interfaces (Pal et al., 2017; Senjam, 2021). This interdisciplinary research has included work on accessing information about a person's immediate environment for visually impaired people (Bandukda and Holloway, 2020; Kameswaran et al., 2020) and wheelchair users (Bird et al., 2019; Mott et al., 2020). New physical interactions and tactile capabilities have also improved the accessibility of digital devices (Chibaudel et al., 2020; Fan et al., 2020). All of these advances create new products, and in turn increase the number of possible product matches to a particular user's needs.

Effective matching of individual need to AT is challenging given the range of dynamic variables that must be considered during user-focused AT assessments. The user's needs, capabilities, environment, and lifestyle will influence the effectiveness of AT (Savage et al., 2019). Qualitative HCI investigations have yielded value-based research and design theories that challenge normative attitudes, including how we study complex interventions like AT adoption (Carmien and Fischer, 2008; Deibel, 2013). These approaches ensure we as designers consider the complexity of the technology adoption process and to understand the need for simplicity especially when designing for people with cognitive impairments (Carmien and Fischer, 2008; Deibel, 2013). However, as the number of new technologies increases, keeping up to date with new innovations becomes a more complex problem and places an additional burden on an already stretched healthcare profession. At the same time users, without access to advice are simply searching the internet for solutions.

We were unable to find prior research which explicitly addresses the problem of information seeking about an assistive technology, which we feel is an essential part of the AT matching process, both for the individual user and AT professionals and stakeholders. Having better mechanisms for searching for information and matching user needs to AT could help overcome barriers that are established in literature exploring AT decision-making, like awareness of AT in general (Andrich, 2020), better user fit to products (Ran et al., 2022), awareness of accessible features on existing devices, and user agency to make informed decisions (Barbareschi et al., 2020). Due to the lack of prior work specifically in the area of AT and information seeking we now look to the wider field of information seeking in HCI.

2.2. Information seeking in HCI

How people search for AT can be informed by the broader HCI research on information seeking. The HCI community has previously addressed the needs of disabled people when searching the internet for information, including the needs of blind coders when seeking information (Storer et al., 2021), and the health information seeking needs of people more generally (Fry et al., 2015). Many information systems already utilise smart features such as recommender systems to curate and present data to users (Atvisor, 2021; Heumader et al., 2022), aiming to make the most relevant information more quickly accessible. Previous work has shown opportunities to tailor and improve user experiences by building user profiles through visited pages and toolbars (Gasparetti and Micarelli, 2007) and predicting search behaviours through a browser

plug-in (Mitsui et al., 2017). Yet the algorithms subsequently used to index, retrieve, and rank data are often driven by underlying data that are themselves biased (Gao and Shah, 2021). Gao and Shah further describe that ordering of search results creates position bias and exposure bias, especially given an algorithm's focus on relevance and user satisfaction (Gao and Shah, 2021). Significant attention has been given to debiasing recommender systems (Chen et al., 2020) and improving their accessibility (Deldjoo et al., 2021), as well as considering how AI-powered systems can avoid entrenching bias (Oneto et al., 2019), specifically regarding people with disabilities (Guo et al., 2020; Trewin, 2018; White, 2020). These emerging trends indicate potential for smart systems to support AT-information seeking. Yet given the sensitive nature of AT need, AT professionals may have specific concerns about AI-powered features curating information that must be considered when designing a system for their use.

2.3. AT information sharing

To address issues like AT abandonment that result from ill-informed need-matching (Phillips and Zhao, 2010), NGOs, manufacturers, and disabled peoples' organisations (DPOs) have created several info-sharing platforms. For example, the EASTIN system is a search engine that aggregates multiple national databases on AT in Europe and provides "documentary evidence of over 60,000 assistive products" (Andrich, 2020; Andrich et al., 2013). The AT Info Map app identifies AT service providers and suppliers across several African countries to improve their accessibility and users' awareness (Visagie et al., 2019). ATvisor.ai piloted a recommender system providing users with personalised results based on self-reported functioning difficulties, informing them of options that may be suitable (Atvisor, 2021). Often, information is collated by specific organisations who focus their communication to particular user groups, or particular regions, which can improve information-sharing to specific populations. However, these efforts can also delay novel advances from making their way into such platforms. The quick evolution of the AT market and information technology is a major challenge faced by all AT database providers (Andrich, 2020).

Yet the challenge of AT information seeking has not been considered as a barrier to broader AT access and has not been supported by practical applications and examples in this research area. In particular, there has been limited HCI research on information seeking within the domain of AT. Our study is therefore set apart by its focus on information seeking, without limiting to specific technologies or pathways, and inclusively defining AT as the systems related to the delivery of assistive products, which maintain or improve an individual's functional independence (World Health Organization, 2018). Our work investigates information barriers that are relevant across a diversity of AT professionals' experience. Overall, we present this intersection of research topics as informative for designing tools that support human decision-makers, rather than aiming to replace them.

3. Methods

3.1. Interviews

Twenty-two semi-structured interviews were conducted with AT professionals, transcribed verbatim, and systematically synthesised using Template Analysis (King and Brooks, 2016; Braun and Clarke, 2019). Authors conducting interviews and analysing data were included in an approved UCL ethics application covering qualitative interviewing and subsequent data management of non-vulnerable AT stakeholders, professionals, and researchers. Prior to interview, each participant was sent an information sheet about the study and returned a signed informed consent document. Interview questions were developed with the aim to understand how members of this group experienced AT information seeking, which is required for their work. Interviews consisted of fourteen open-ended questions, with four to five questions representing each of the main topics of interest: common AT information seeking strategies, limitations to AT information access and use, and the possibilities afforded by AI.

3.2. Participants

AT professionals were chosen as our primary study focus because these individuals have extensive (most likely daily) experience specifically searching for AT information. Their information-seeking challenges and successes often have a major influence on the availability of AT for individual users. Our participants were identified through the professional networks of the World Health Organization's Global cooperation on AT (GATE) community and through the Global Disability Innovation Hub and AT2030 networks, and snowball sampling: we asked interviewees to suggest colleagues who would be interested to participate. Individuals were considered AT professionals if they currently worked in one of the "5 P's" of the AT world as defined by the World Health Organization: People, Products, Provisioning, Personnel, or Policy (Desmond et al., 2018). Individuals known by authors to meet these criteria were selected from this network. Twenty-two responded affirmatively to our e-mailed invitation for an interview. Many had experience in additional fields—combining both primary/current and secondary/previously held positions, 12 had experience in policy research and implementation, 10 in clinical AT assessment and training, and eight in product innovation and procurement. Four were based in LMICs and three are AT users. Full participant details are provided in Table 1:

3.3. Analysis

Our thematic analysis process combined both inductive and deductive coding, relating to the Template Analysis approach described by (King and Brooks, 2016). Three authors participated in interview coding. We initially familiarised ourselves with the data by reading two interviews each and conducted preliminary coding by employing an inductive approach and applying open and in-vivo coding methods for every line of the six unique interviews. All coding was conducted in MAXQDA 2020 (VERBI GmbH, 2021). After this step, all codes were reviewed by authors in a group discussion. Similar codes occurring in

Table. 1
Study participants.

Participant ID	AT user	Country	Country income profile*	Current role	Secondary role
01	–	Spain	HIC	Policy	–
02	–	UK	HIC	Policy	–
03	–	Cyprus	HIC	Policy	Provider
04	–	UK	HIC	Policy	–
05	–	Denmark	HIC	Policy	–
06	–	Italy	HIC	Policy	Innovation
07	–	UK	HIC	Policy	Provider
08	–	UK	HIC	Policy	Provider
09	Yes	UK	HIC	Innovation	–
10	–	Brazil	MIC	Provider	–
11	–	Germany	HIC	Innovation	–
12	Yes	UK	HIC	Policy	–
13	–	UK	HIC	Innovation	–
14	–	Portugal	HIC	Provider	–
15	–	Israel	HIC	Innovation	Provider
16	–	Cambodia	LIC	Provider	–
17	–	UK	HIC	Policy	Provider
18	–	Ireland	HIC	Policy	Provider
19	–	Brazil	MIC	Policy	Provider
20	–	UK	HIC	Innovation	–
21	–	Germany	HIC	Innovation	–
22	Yes	Kenya	LIC	Innovation	–

*Country income profiles are set by the World Bank and abbreviated to HIC (high-income), MIC (middle-income) and LIC (low-income).

multiple interviews were identified, given an overarching thematic name, and defined by the group in a clustering process. These themes were sorted as either main-themes or supportive sub-themes, based on their relationship, frequency of occurrence, and breadth. This process produced a template as a standardised coding tree, based on 30% of our data. Transitioning to a deductive approach, authors then applied this template to line-by-line code/recode the interview transcripts. An 'other' code option was included to permit coders to indicate new themes that were not evident in the initial six interviews, allowing some further development of the coding template.

Authors again discussed the resulting main themes and consolidated these into comprehensive AT information barriers to organise our presentation of results. Authors then developed values in relation to these barriers, which guided the development of design implications for an AT information platform that would align with the standards of this user group and merit further exploration.

4. Results

We present our results in three sections, in line with our research questions: (1) common search strategies, (2) themes characterizing AT information limitations, and (3) themes concerning the role of AI in AT. Each section of Results consists of the main- and sub-themes most important to our interviewees, with illustrative quotes.

4.1. Common search strategies

Our interviewees represented a variety of professional and lived experiences around the world, and naturally reported familiarity with a diverse range of sources for seeking and sharing information. Professional networks and colleagues were the most used, which reflects the insular nature of the professional AT world. Alternative and social media, including Facebook, Twitter, LinkedIn, Kickstarter, and independent blogs were mentioned by 14. Academic sources, including peer-reviewed literature, were cited as relevant sources by 13. However, face-to-face encounters mentioned by 15, which include clinical visits, attending conferences in person, and examining AT at tradeshows and in shops, and were specifically noted as helpful and informative, because it is often easy to have specific questions answered and actually touch and try assistive products. Active searching overall via search engines and databases was mentioned by 16. These information pathways were relevant to information about products, policies, market research, and training.

4.2. AT information limitations

Though each participant had a unique approach to responding to our questions, recurring themes were often evidenced in nearly all interviews. Six main-themes regarding AT information seeking were identified from the interviews. These themes are supported by their three most common sub-themes (i.e. occurred in the most interviews), which are paired with explanations and direct quotes. Fig. 1 provides an overview of these themes.

4.2.1. International marketplaces

The AT marketplace is international and varies substantially by country, which was identified as the most common challenge to seeking AT information. Governments prioritise AT funding and plan its delivery systems differently, making it difficult to characterise regional markets, and laborious to search information on a country-by-country basis. P05 notes this is particularly taxing when it comes to user data:

> "Detailed user need information in low income countries in general I find quite difficult to find accurate numbers on, and the governments of countries themselves often don't have them because they don't prioritize this specific area" (P05).

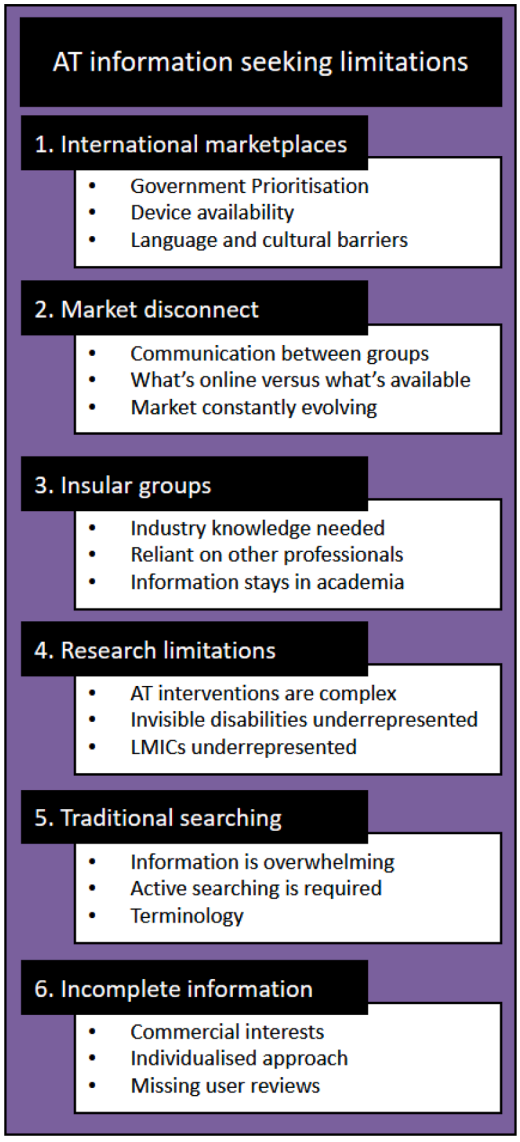

Fig. 1. Main and sub-themes associated with AT information seeking limitations.

Government prioritisation of AT in terms of funding and coverage has a significant impact on what providers can offer their clients and patients. This influences the level of individual factors that can be considered when prescribing AT, like the user's goals and wants. P14 describes how their capacity to provide suitable AT was increased when working in a wealthier country:

> "For me, the difference now is the government, because here in Portugal we really can explore more potential in the product for the clients. So for me, the context changed all my view about the AT because in Brazil it was like I can think only for this part of the population because of the money…the context changes…my mind, now I can see more details of the product and to think more critical about how to indicate one or not the other product and to… work more conscious… and to assessment the demands of the client" (P14).

These variations further affect **device availability**, which influences what products providers are aware of and can prescribe and what clients can use or afford. When providers are unable to prescribe products, the perceived demand for these devices will be low and therefore not garner

investment or prioritisation from the government. Yet P02 illustrates that increased information on individual products will not equate increased availability, and further explains how efforts to centralise all information globally can even do a disservice at the individual level:

> "Just having lots of information only to find out that it's not available in your community, in your country, in your language is actually not much help to people. How we present information to reach into the communities, in that way, is going to be really important…there is a danger over centralization in that it can raise expectations unreasonably" (P02).

When expensive, high-tech/high-maintenance ATs are not available for procurement due to in-country factors, providers often are not able to explore how a new technology may benefit users. In P16's case, their prosthetist students can't even get hands-on experience with these high-end ATs:

> "In [Cambodia]…we can show to the student only the theory, but… they don't have much practical involvement…they're doing with some practical work with new technology, but basically they are working with the low technology, not the modern technology…for the new technology, we first we can see through video, we can learn the theory only, but we cannot touch much" (P16).

Language barriers were often mentioned. Most AT information is available in English or European languages, putting info seekers in many LMICs at a disadvantage.

> "…things like, you know accessibility in terms of language…is this stuff out there actually culturally acceptable?" (P07).

P07 expresses that, even if verbatim translation can be achieved, a language barrier can include terminology and cultural understandings that may not translate effectively, particularly where product guidelines and services may be tailored for a specific context and exported to another without any adaptions. Further, stigma around AT use itself remains an issue in many settings and the language used to communicate information can affect how it is received.

4.2.2. Market disconnect

Difficulties associated with **disconnected marketplaces** were noted by most interviewees. Frequently, the root of this problem manifests as a lack of communication between different AT market stakeholder groups (which are numerous and varied), including users, designers, and providers. These gaps in understanding result in a lack of awareness of challenges faced by individual users and ultimately under-met needs, as P12 explains:

> "…being a limb user all my life, I've never really, and like and I'm 37, I've never really got to the point where I've actually ever had a socket that is 100% meeting my needs, and I think that to me, having spoken to other patients when I'm in the hospital, having spoken to other people who have disabilities similar to my own, is a common problem…it's something that there isn't a lot of awareness, and when you speak to engineering graduates or when you speak to people about it, they very often are like, well, we didn't know that was the problem, or, we didn't know that was a challenge that was existing" (P12).

The variation in what is online and what is available in the real world is another effect of the disconnected marketplace, especially as many novel solutions are not effectively scaled up to meet consumer needs. Small-medium enterprises may be edged out by bigger competition or obfuscated by their marketing in search results; these enterprises have a high rate of failure, as many get to a point and can't go to scale. Difficulty staying informed in this aspect is explained by P18:

> "Especially with novel technologies, you don't know what stage of development there at, so sometimes you'll find something in the literature and it's something that's being developed into great idea, but then actually finding it in the real world, it often isn't there" (P18).

The AT marketplace is constantly changing and evolving, making the design of long-lasting products, partnerships, and delivery systems a significant challenge.

> "There is…more and more innovation coming in, to help the professionals involved, you know the [occupational therapists] and the prosthetists, physio therapists, and clinicians who need to think through the provision of these tools, being able to see a broader picture is very important" (P20).

P20 notes that changes in these areas make staying informed with other sectors even more difficult for stakeholders like providers, who must know all the options available for a user to make truly informed decisions.

4.2.3. Insular stakeholder groups

Nearly all of our interviewees mentioned limitations that reflected the **insular nature of the professional AT world**. To access and interpret siloed AT information, many said an individual needed to have professional experience or industry knowledge. P12 expresses this in terms of academic research:

> "I'm just really not sure, unless you work in that field, or unless you're an academic how you would actually access that information" (P12).

Almost half described their own information searching strategies as primarily **reliant on colleagues or other professionals**. This indicates that an information-seeker without professional connections in the AT world may be locked out of a lot of shared knowledge.

> "We often rely on the experience of other professionals that have been in the field for longer and that can give us clues of where to look and what to do" (P19).

These segmented networks affect all disciplines of AT professionals, but are particularly noted by professionals who change fields, like P03:

> "I'm not a developer or designer so it's easy to miss out new developments and it's good to have contact with the industry for this and I'm fortunate enough to have this involvement…after I left the practitioners fields, it's harder to get information on the development of products. When I was in the field assessing children and trying to locate assistive technology per say, it was easier for me to have these contacts and have this information" (P03).

A substantial portion of **AT information is published by, for, and within academic research communities** whose members are accustomed to reading that type of material. This information alone is less useful to those without access to journals or experience interpreting academic writing; P02 explains this makes academic communities more insular:

> "We have a huge issue in terms of how research is disseminated, as research is generally disseminated within an academic community and to nobody else" (P02).

Additionally, this information is often restricted by paywalls, which

disproportionately excludes information seekers from LMICs.

4.2.4. Limitations of publishing AT research

Limitations for conducting and publishing AT studies were noted as barriers to seeking and sharing information. AT is a difficult intervention to study because it is a complex, individualised approach; studies often have very small sample sizes and inconclusive results, which as P18 explains, make them harder to publish:

> "*…we publish research in the world of Medicine and science, which likes to have discrete, controllable interventions that can be compared against a control of some kind and don't take into account the complexity of the intervention…that's a problem in within the AT data literature in general,* is *we have a very, very poor understanding of what gold standard research would look like for complex interventions like AT, because it's not just the technology, it's everything else; the entire service provision process that needs to be assessed, and we're just really, really bad at evaluating it*" (P18).

Unique market contexts further prevent the extrapolation of findings to different populations and therefore limit the amount of information that can be used. An example of this is given by P11:

> "*We might have one health insurance in Germany, and we can use it to extrapolate for different areas, but…most of the people are German and then you don't have as much insight into any other, you know, you can't really scale it beyond Germany because it's limited by who's sampled*" (P11).

Invisible disabilities are also underrepresented in the literature. Individuals seeking information for these have a more substantial challenge, as P15 notes that information is lacking:

"*Neglected areas of disability regarding assistive technology, as I see today, are cognitive impairments and mental health. So much to do in these areas. So many interesting solutions are there or can be developed. And those areas don't get enough space*" (P15).

Further, conducting research in LMICs and settings with low government prioritisation of AT can be especially demanding, resulting in less research conducted in contexts where it is needed most and **low LMIC representation**:

"*It becomes even more important is when we talk about low- and medium-income countries where we're trying to build the markets. Emerging markets were trying to look at innovation. And the cost of access to research is probably way beyond what certainly individual researchers and actually many institutes can actually afford*" (P02).

It is especially difficult for individuals to research or stay informed on intersections of underrepresented areas in AT.

4.2.5. Traditional search limitations

Standard searching is ineffective for AT information due to the previously discussed limitations. Normal database searching is not an effective solution because the information is overwhelming to sort through. P16 notes how this can be particularly discouraging for individuals in need of AT:

"If we search and then nothing found, and then again we do it, nothing found, and then it makes the people who want to search about that technology, they want to give up, they don't want to continue doing" (P16).

Active searching is also required to remain informed. In addition to the prerequisite of industry knowledge, search skills, and a reliable broadband connection, an information seeker needs a great deal of time to navigate the overwhelming number of options they may find, which P17 describes as a limiting factor:

"*…the limiting factor there is having the time to sit down and skim through all the different text reader, screen reader, screen magnifications, and then think OK, is that screen magnification now being outpaced by what Microsoft are offering?…those are the things I don't have time to do*" (P17).

Answering specific questions is further complicated when they concern underrepresented areas in the literature, like invisible disabilities or LMIC settings. They are obfuscated in searches by results from the global north, where AT design and manufacture is concentrated:

"*The other thing which I think we struggle with is hearing about innovation and new ideas which are not based in the US or Western Europe. Those new stories do not pervade well, and you actually need to pick/find your sources for those types of news stories to keep an eye on them…It's actually quite hard to get that information unless they're really pushing that news out into US media or Western European*" (P02).

P02 describes that the onus is on LMICs to get their work proportionate attention. However, **differences in terminology** also complicate traditional information seeking methods, especially as they further cross languages and cultures. Policies and news relevant to AT and PwD may not include certain key terms, or use synonyms that the seeker wouldn't know:

"*If you know what AAC stands for and what it means you've got a much better chance of finding out about it, but for the vast majority of people, if I stop somebody on the High Street and said, 'do you know what AAC means?' they wouldn't have a clue. And yet, if their husband had a stroke and needed a communication aid, they wouldn't know where to start without that, that information. So I think terminology is, partly, a boundary for accessing further information and finding out what you need to know*" (P04).

P04's example describes how awareness of the actual names of relevant products also inhibits an individual's search.

4.2.6. AT information is often incomplete

Even when relevant information can be located, it may not provide a complete picture. **Incomplete information** was cited by almost all our interviewees as a barrier. Most often, this was due to commercial actors influencing what information is available. As there is little independent advice available, information seekers are heavily reliant on the suppliers' promotion of their devices, which means commercial actors can control the discourse on the economics of access to assistive devices. This is described in depth by P06:

"…where we see that there is a more direct relationship between the user and manufacturers, usually the manufacturers tender to disclose more information. If it is only mediated by, say, third parties like public agencies or insurances they tend to disclose only the minimum set of information as required…It is a cultural bias…it seems that in the UK, there is a wide awareness of assistive products and there is a large population of professionals such as occupational therapists that know about assistive technology, so companies tend to be more, let's say, careful and precise and to be more prepared to disclose quality information. There are countries where some assistive technology areas are very little known or even not considered by the public system. I have in mind, for example, my country Italy. Very few people know that cutlery, for example, could be helpful for people with disabilities, or environmental control systems, and so there is little attention and in parallel there is more difficulty to get information" (P06).

The effects of this influence can manifest in the non-disclosure of negative aspects of work or the price of the product, which prevents device comparison. These interests further affect what AT is available in a country and may be responsible for information searches that overwhelmingly turn up marketing materials. It can be difficult for individuals to distinguish between these and factual information. Matching individuals with suitable AT requires an **individualised approach**, which complicates the process of acquiring comprehensive information. An individual's wants and needs must be considered with their environment and context, as recommended by P15:

"…when someone is looking for a wheelchair, he has his unique profile and his personal goals and he absolutely needs something more than a wheelchair, something that is connected to his daily functioning and relates to his symptoms" (P15).

Providers who lack a holistic understanding of AT or a user's complete context may apply a generalised view when they prescribe a product. This results in an un- or under-met need and impacts the user's

functioning, as in this example provided by P14:

"…we have for example, a girl, a younger girl with dystrophy, with a lot of potential, and this girl in prescription received a simple wheelchair, a manual chair. But it's not make sense, because this girl, she lives in a place very difficult for a manual wheelchair; she needs a power wheelchair…the girl would be much more function with a power wheelchair. So I think that people try too general, try to simplify the issue of the AT" (P14).

User reviews and lived experience were often considered a crucial piece of missing information. When product negatives are withheld by manufacturers and suppliers, issues don't come to light until the products are actively being used, which leads to under-met needs and prevents designers from understanding how to improve products. P18 notes that communication channels, particularly those between users and other stakeholder groups, are insufficient:

"There's never been…a place where people that are users of these products are kind of almost outlining the difficulties they are facing and the things that they are encountering, or at least if they're saying it, they're telling it to their prosthetist or their physician, but that's not being relayed back into a big, kind of, a bigger conversation" (P18).

User experiences with ATs are difficult to find, especially for new devices, and often by design.

4.3. AI's role in AT information seeking

Interviewees varied significantly in familiarity with AI, machine learning, or recommender systems, from, not familiar whatsoever, to designers of AI-based applications. Though fewer participants offered their comprehensive perception of AI, overarching themes were still evident across most interviews. These concerns and opportunities highlight a space where AI may power tools to empower, but not replace, human assessors. Fig. 2 lists the main- and sub-themes identified throughout questions on AI's current and future role in AT.

4.3.1. Expanding accessibility

Most participants expected that **AI would expand accessibility overall**, and though there are privacy and data challenges to overcome, the technology had great potential to make life easier for many PwD. AI's integration to specific products and applications was frequently mentioned and many examples were detailed by interviewees, often

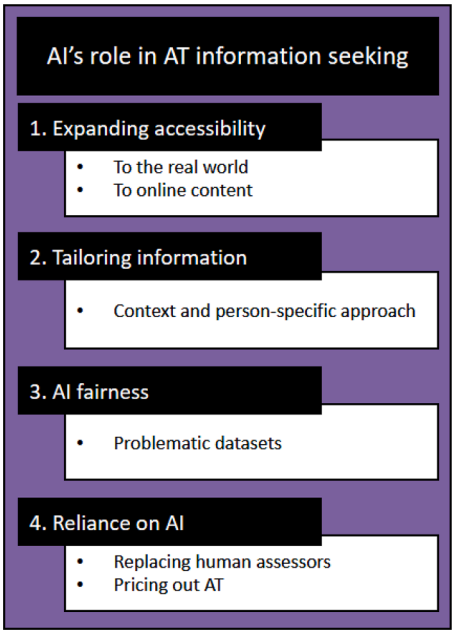

Fig. 2. Main and sub-themes associated with AI's role in AT information seeking.

specific to their AT expertise, like P14's:

"I think there could be a lot of opportunities with AI around vocabulary for people with little or no speech, so being able to personalize people's interests in terms of vocabulary that's made available to them based on kind of more intuitive responses to their use of, for example, social media…which could generate vocabularies that could be accessible in their own communication devices…they are reliant on what vocabulary is made available to them, and that's not necessarily particularly responsive to change in people's lives and their interests in their environments and what's happening in the world around them…For people who use AAC, being unable to communicate their thoughts and feelings about what COVID-19 means to them simply because they don't have the vocabulary, well, with AI in the future, that potentially could offer solutions to that" (P04).

AI is also becoming instrumental for expanding accessibility to digital content and information. These approaches support an individual's autonomy by empowering them to make informed decisions about their support systems. P15 describes how multiple groups would benefit from a centralised collection of knowledge:

"I would talk about collaborative intelligence, meaning that we harness the power of AI to be integrated with experience and preferences of the user and the professional consulting about assistive technology and together create something that is bigger than the whole and supports the user in the decision-making process" (P15).

Though not a replacement for human assessors, smart information systems would be useful to users and providers to scope available options.

4.3.2. Tailoring information

Tailoring information is crucial for informed decision-making regarding AT. The process must work for the person as well as their context, or unsuitable products will be abandoned by users. P15 expresses that this requires a developed and highly personal approach:

"…the importance of personalization…information is overwhelming and if, and we're talking about client-led processes or client-centric processes, so, I would suggest personalization as a basic important thing. I would suggest using a biopsychosocial model, not classifying assistive technologies only through diseases or functionalities, like eating and drinking, that's not enough. We need to think about the person" (P15).

The automated recommendation of AT and information will be more appropriate where contextual factors, like national policies, health coverage, service locations, and local accessibility are considered. P07 notes that we cannot just assume a system will be universally effective:

"…all these things need to be validated and all of these things need to be validated in the settings that they're going to be used in" (P07).

This system must deliver relevant information for user groups in as many contexts as possible, or it will further entrench a bias for searching and sharing information from a particular region.

4.3.3. AI fairness

AI's capacity to replicate discrimination against PwD was a concern brought up by many interviewees. AIs are generally trained on huge datasets which are not often possible to accumulate for disability and AT. If trained on biased, uncorrected, or exclusionary datasets, the resulting system will not treat PwD fairly:

"AI will also have a negative effect when it comes to, to further discrimination if this is used for the general public without acknowledging that there is a human diversity in our societies and there is no such an average user there" (P01).

P01's concern reflects the need for better data collection and considerate algorithm design. Currently, our data and AIs are not seamless enough to support integration with everyday devices for these populations.

4.3.4. Reliance on AI

Concerns about the increasing **reliance on AI** were cited by most participants. These most often centred around decision-making systems

replacing human assessors for AT, as expressed by P01:

"I wouldn't rely on this kind of tool to run the assessment on which information or which specific AT solution is most suitable for me…the human professional will have more in mind, more nuances on, on the communication with the user…So the choice of the appropriate piece of a AT would be most likely correct…it brings up a lot of opportunities, but on the other hand you don't want to leave all the decisions to be automatically generated, especially when it comes to decisions that affect people" (P01).

The consequences of an incorrect decision must be understood and its reasoning must be visible and interpretable by users, who can then apply their own judgement to agree or disagree. AI-powered solutions are also not sufficient to solve the fragmented AT delivery systems that accompany fragmented information pathways:

"…AI-driven systems need to be integrated within a broader escalation model of service and support. Ultimately, there will be a number of people for whom an AI driven engine only gets them so far down the journey, and they're gonna need various tiers of human intervention to help address that. That will change as our algorithms and our data gets better and better over years and increasingly more and more people will find solutions to what they need using AI driven solutions. But at the moment that needs to be within a matrix and a framework of escalation of needs and support" (P02).

P02 expresses how increasing awareness and encouraging in-country prioritisation of AT may contribute to establishing a framework for escalating needs and support, where AI could contribute key services. However, P22 notes the increased integration of AI in physical AT brings about the concern of **pricing out more people from high-end assistive technology**:

"…one of the biggest barriers around AT is affordability and the trend has been, it has seemed that the more high tech the AT, the more expensive this technology is and it's going to be a need to make it more accessible from an affordability perspective" (P22).

This scenario would entrench existing disparities in AT access, particularly in settings where AT awareness and innovation are not appropriately prioritised and funded by governments. Incorporating AI-powered systems will affect the price, maintenance needs, and operating skillset for most devices, which all present risks of restricting the device's potential user population.

5. Design implications for at information seeking

Authors consolidated the main themes into four key AT information barriers and identified relating values in/directly indicated by study participants. Design implications for an AT information platform were developed to address the barriers while prioritising the values. Fig. 3 connects these barriers, values, and implications, demonstrating a design pathway for breaking down siloed information in this sector based on the input of AT stakeholders. This overarching aim may be accelerated by incorporating smart features into a centralised information platform to improve its capacity to evolve with the marketplace and support individuals' informed decision-making. The disparate results from our initial literature review and our thematic Template Analysis demonstrate these values and design ambitions are not widely implemented in the field.

5.1. AT information barriers

Fragmented marketplaces were described by most interviewees, especially in terms of internationality and disconnect between sectors. Keeping up with local and international marketplaces is further complicated by the broad, rapidly expanding diversity of products that characterises the wider AT sector.

Insular information networks amongst stakeholder groups entrench unequal access to information. Examples of this include industry actors keeping data in-house and AT research (where it exists) being written/provided mainly for academic audiences. Potentially impactful research and data are often not available or accessible to all who could use them.

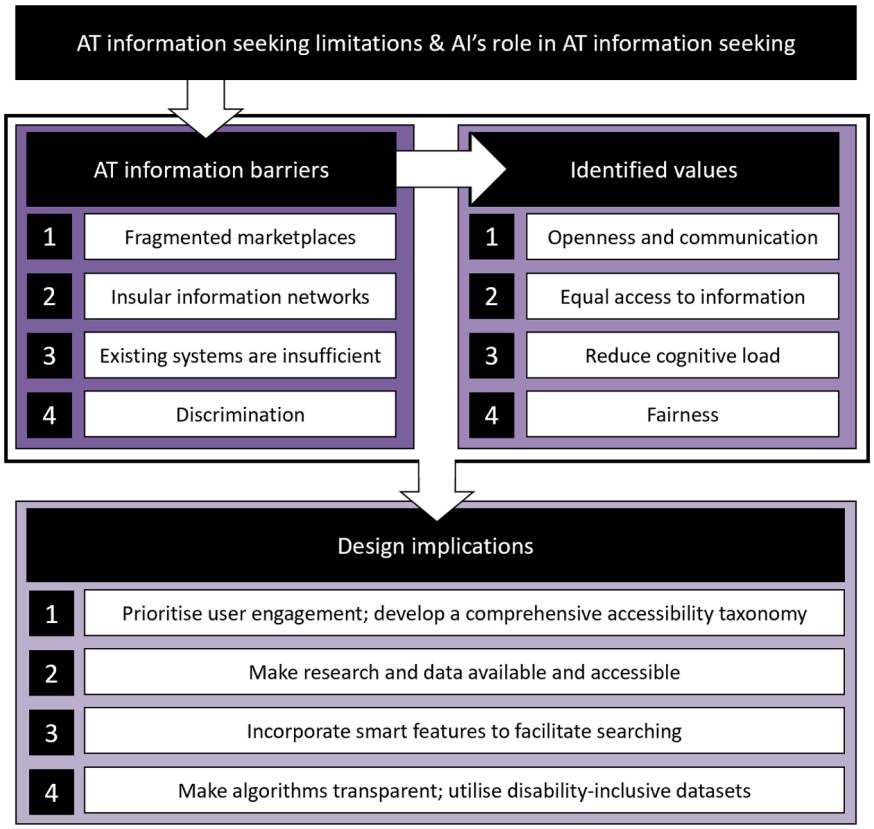

Fig. 3. Breaking down siloed information: Information barriers, values, and design implications.

Existing systems are insufficient to support searching needs, especially as information required to effectively match user needs with AT is multi-faceted. Interviewees further expressed how already siloed information is made more difficult to access by language barriers, variation in terminology and definitions, and cultural appropriateness.

Discrimination was a major concern of interviewees, particularly when discussing the potential role of AI in any part of the AT provision pipeline. There are many opportunities for smart features to entrench existing biases and misrepresentation of people with disabilities through the filtering and ranking of AT information. Information from, or relevant to underrepresented user groups (e.g. individuals from LMICs or with invisible disabilities) likely won't be ranked highly in an individual search, making it even more challenging to access AT in certain contexts. It has been demonstrated that information retrieval tools reliant on AI for queries, autocompletion, search result ranking, and summarising content may return stereotyped or misrepresented answers concerning people with disabilities (Guo et al., 2020).

5.2. Identified values

In combination, the diverse information barriers communicated by interviewees indicated they value openness and communication, equal access to information, reducing the cognitive load of searching, and disability fairness when considering AI involvement. Each value relates to each barrier, and may be further used as a framework to guide how an AT information platform is designed and AI components are incorporated (Holloway, 2019). Fig. 3 demonstrates how this design pathway emerges from considering barriers and values together.

5.3. Design implications

There are many opportunities to address the information barriers while respecting the values expressed by the AT stakeholders that merit further investigation. As AT information seeking has not been fully addressed in the HCI community, our design implications reconnect more broadly to HCI research.

To encourage openness and communication amongst actors, incorporating user reviews at each stage of the provision pipeline can bringing useful, often missing information to the forefront (Hedegaard and Simonsen, 2013). Currently, there exists no platform dedicated to AT information where user engagement is given sufficient space.

Overall, there is significant potential for smart features to improve AT information seeking by reducing the cognitive load of active searching. An inclusive taxonomy can be developed to inform a web crawler that could identify relevant information from alternative sources and underrepresented groups that is more challenging to find (White, 2020). This dataset could be generated from user reviews (Hedegaard and Simonsen, 2013) and could facilitate searching while supporting fairness. Yet there is no existing dataset to meet these needs.

Tailoring information through recommender systems (Chen et al., 2020), maintaining their relevancy and fairness in a rapidly changing marketplace with a smart web crawler (Dahiwale et al., 2010), and disseminating data more broadly by generating lay summaries of specialised research (Dash et al., 2019) can all support equitable access to information. Our literature review and findings demonstrate this intersection has not been effectively addressed with respect to AT information, either in HCI or population health literature. This gap shows a lack of consideration for the ineffectiveness of active searching for AT info, and for the role of AT info seeking as a component to broader AT access.

To support disability fairness when designing a smart platform, sorting algorithms can be presented transparently (Sacharidis, 2020) and based on disability-inclusive datasets. At present, little effort has been placed in improving AI systems' fairness specifically where their limitations in accommodating people with disabilities are not shared by non-disabled humans (Nakamura, 2019). This inconsideration may result in poor quality of service or allocation, denigration, stereotyping, or over/underrepresentation (Guo et al., 2020).

6. Limitations

Our study benefitted from a broad diversity of professions represented in our study population, however participants varied more in professional experience than global context. Nearly all currently work in high-income countries, predominately in Europe. This is due to our own organisation's European origin, as well as the concentration of AT design and manufacture, and increased AT funding in the region. These factors shaped the network of primary contacts from which we initiated snowball sampling. We also are missing North American perspectives, and as a major player in the AT and digital sectors, these perspectives must be included in future research on this intersection.

AT users also have lower representation in our study. Overall, they are underrepresented in academia and other professional roles, which is both a latent cause and a result of an inaccessible and exclusionary professional environment.

Interviews were conducted in English, and for many interviewees, this was not their first language. Though all confirmed their comfort with being interviewed in English, difficulties expressing their ideas during interviews may have limited their explanations or affected our interpretation of their responses.

7. Conclusion & next steps

In this study, we follow the approach set out in the DIX manifesto: we worked with the knowledge that disability inclusion is a wicked problem and sought to discover the value and usefulness that a disruptive approach to information seeking would have to a wide range of stakeholders (Holloway, 2019). In doing so, we have identified that information access is a significant bottleneck to AT access, presenting a unique opportunity to construct a platform to centralise and encourage AT information-sharing and explore smart features that would support this aim. The platform will be most effective if co-designed with AT users, innovators, and all other stakeholders, in accordance with practical and ethical guidance derived from our interviews and related work. The considerate planning and execution of this co-design process constitutes the next step for future research. This inclusive approach may produce the results that provide researchers with strategies for writing unbiased algorithms to connect information across disparate communities like international markets. These are two critical stages in the initial phase of realising AI-powered AT information sharing and ensuring this solution is effective for all communities.

CRediT authorship contribution statement

Jamie Danemayer: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Cathy Holloway:** Conceptualization, Methodology, Validation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Youngjun Cho:** Conceptualization, Methodology, Writing – review & editing. **Nadia Berthouze:** Writing – review & editing. **Aneesha Singh:** Writing – review & editing. **William Bhot:** Validation, Formal analysis, Data curation. **Ollie Dixon:** Formal analysis. **Marko Grobelnik:** Conceptualization. **John Shawe-Taylor:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

Authors are especially grateful for the time, expertise, and insight contributed by all interviewees. This research was led by Jamie Danemayer on behalf of the Global Disability Innovation Hub in her role as Researcher, supported by the AT2030 Programme which is funded by UKAid, project number: 300815 (previously 201879-108). However, no specific funding for this study exists. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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