

Reading-Assistance Tools Among Deaf and Hard-of-Hearing Computing Professionals in the U.S.: Their Reading Experiences, Interests and Perceptions of Social Accessibility

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Automatic Text Simplification (ATS) software aims at automatically rewrite complex text to make it simpler to read. Prior research has explored the use of ATS as a reading assistance technology, identifying benefits from providing these technologies to different groups of users, including Deaf and Hard-of-hearing (DHH) adults. However, little work has investigated the interests and requirements of specific groups of potential users of this technology. Considering prior work establishing that computing professionals often need to read about new technologies in order to stay current in their profession, in this study, we investigated the reading experiences and interests of DHH individuals with work experience in the computing industry in ATS-based reading assistance tools, as well as their perspective on the social accessibility of those tools. Through a survey and two sets of interviews, we found that these users read relatively often, especially in support of their work, and were interested in tools to assist them with complicated texts; but misperceptions arising from public use of these tools may conflict with participants' desired image in a professional context. This empirical contribution motivates further research into ATS-based reading assistance tools for these users, prioritizing which reading activities users are most interested in seeing the application of this technology, and highlighting design considerations for creating ATS tools for DHH adults, including considerations for social accessibility.

CCS Concepts: • **Human-centered computing** → **Accessibility**; **Empirical studies in accessibility**;

Additional Key Words and Phrases: Automatic text simplification, reading assistance, people who are deaf or hard of hearing, social accessibility

ACM Reference format:

Oliver Alonzo, Lisa Elliot, Becca Dingman, Sooyeon Lee, Akhter Al Amin, and Matt Huenerfauth. 2022. Reading-Assistance Tools Among Deaf and Hard-of-Hearing Computing Professionals in the U.S.: Their Reading Experiences, Interests and Perceptions of Social Accessibility. *ACM Trans. Access. Comput.* 15, 2, Article 16 (May 2022), 31 pages.
<https://doi.org/10.1145/3520198>

This material is based upon work supported by the National Science Foundation under award No. 1822747.

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1936-7228/2022/05-ART16 \$15.00

<https://doi.org/10.1145/3520198>

1 INTRODUCTION

Automatic text simplification (ATS) incorporates various computing techniques for rewriting or modifying text to improve its readability and understandability. Prior work has investigated the use of ATS as a reading assistance technology for several user groups, such as people with aphasia or dyslexia [23, 54], language learners [10] or low-literacy adult readers [71]. As an emerging field, most work in this area has focused on evaluating the underlying simplification technologies, i.e., the quality of the output produced by ATS systems (e.g., [57]), evaluating the linguistic needs and benefits from ATS for different user groups [7, 38, 44, 50, 55], and investigating certain design aspects of the potential user-interface of such tools [7, 56]. Only one prior work, however, has focused on investigating the needs and interests in using these tools among specific user groups in a specific domain, namely, adults with autism reading online reviews [74]. However, no prior work has investigated reading-assistance needs and interest among people who are **Deaf or Hard of Hearing (DHH)** or the context of a computing professional, nor whether specific reading tasks impact users' interest in ATS-based reading assistance tools.

Approximately fifteen percent of United States adults are DHH [15], and prior research has found great diversity in literacy skills among these individuals (e.g., [12, 27, 68]). While many DHH adults are strong readers, some studies have suggested that over 17% of deaf adults can be considered as having low literacy [27]. Research has also identified lower educational outcomes among DHH adults when compared to hearing peers [28], as well as lower rates of employment and salaries [70]. While written language literacy is necessary in personal and social contexts, it is also important for professional success in many fields. Prior work has established that computing professionals often need to learn about new topics on their own to keep their technical skills up to date [61], largely relying on text-based resources [75]. This may pose a challenge for computing professionals who are DHH and have lower literacy levels. Furthermore, prior **natural language processing (NLP)** research on ATS technologies has suggested it may be useful to collect additional datasets from specific user groups and/or vocabulary in specific domains to determine how that may impact the effectiveness of their technologies for benefiting end users [42]. These trends motivate our study in which we explore the interests and needs of DHH individuals with experience in the specific field of computing and **information technology (IT)**, in regard to ATS-based reading assistance tools.

People who are DHH are already underrepresented in the computing field, with a recent Stack Overflow survey finding that only 0.8% of respondents identified as DHH [3]. This further motivates our research on potential barriers to professional success and how to mitigate those. However, when conducting research into potential assistive technologies for the workplace, it is also important to consider the *social accessibility* of these technologies [64, 65], a term that encompasses the social implications of using assistive technologies (as opposed to their functional purposes), including potential issues they may bring in this context and how to mitigate those.

This manuscript is an extended version of a conference article originally presented at the 2020 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'20) [6], which presented a study investigating the reading experiences of DHH adults in the computing field, and their interests in ATS-based reading assistance tools. That study consisted of an online survey of 32 DHH adults with work experience in computing and IT field, followed by interviews with five respondents to gain a deeper understanding into the survey results. Our results suggest that the majority of participants read several times a week, mostly on an electronic screen, for work or academic purposes. Survey respondents also reported frequently used workarounds when encountering complex text, and "strongly agreed" with being interested in ATS-based reading assistance tools.

This extended manuscript additionally presents a second interview study with seven DHH adults with experience in computing and IT fields. In this new study, we investigate their

perspectives on what they value at work, how those values relate to personal adoption or issues of social accessibility of ATS-based reading assistance tools, and what design aspects may help mitigate potential social accessibility issues in a workplace context. Our findings suggest that participants want to be seen as competent and reliable, but public use of ATS-based reading assistance tools may come into conflict with that desired image because of a perceived relationship between reading skill and intelligence. Our findings also include insights into design solutions to help mitigate the potential social accessibility issues identified.

The contributions of this work are empirical:

- Our findings on the requirements of DHH individuals in the computing field motivate the need for further technical and design work on ATS-based reading assistance tools for this group, suggesting that they frequently read on electronic devices to learn about new topics for their work, and they had a strong interest in such tools.
- Our study provides a prioritized list of: (a) the most frequent workarounds DHH computing workers currently use to understand complicated text (with the two most frequent being analogous to typical ATS approaches), (b) reading purposes for which these individuals would be interested in using ATS, and (c) their most frequent purposes for reading text.
- Our findings also identify social accessibility issues in the context of DHH adults using ATS-based reading assistance tools in a workplace environment. These issues are related to a perceived relationship between reading skill and intelligence, which may come into conflict with how participants want to be seen in a professional context if they are seen using tools that may imply a lack of reading skills.
- A discussion of the implications of our findings for the design of ATS-based reading assistance tools, which: expands prior research on DHH users' preference for such technologies providing autonomy [7] by identifying new design variables to consider related to autonomy; highlights DHH users' concerns about ATS accuracy, which had not been previously been explored in prior work; and suggests potential design directions that may help mitigate social accessibility issues.

1.1 Structure of This Article

The rest of this article is structured as follows: Section 2 summarizes the background and related work for our article, as well as the research questions we explore. Then, Section 3 describes both parts of our first study, which focused on the reading experiences and interests in ATS-based reading assistance tools of our participants. Section 4 then summarizes the results of our first study. Sections 5 and 6 describe the method and results from our second study focused on the social accessibility of the tools. The results from both of our studies and their implications are discussed in Section 7. Finally, Section 8 outlines the limitations of our work and avenues for future work.

2 BACKGROUND, RELATED WORK, AND RESEARCH QUESTIONS

In this section, as context for our work, we first describe prior work on the use of ATS as a reading assistance tool for DHH adults as well as other user groups who may benefit from such technologies. Then, we describe research looking into assistive technologies for DHH adults in a workplace context, as well as DHH adults' general reading habits. We then look into research on social accessibility and assistive technologies, including related work on the social accessibility in technologies for DHH users. Finally, based on the gaps identified from prior work, we outline the specific research questions investigated in this study.

2.1 Automatic Text Simplification as Reading Assistance Tools

Research using standardized testing has observed median reading levels of fourth-grade among DHH high school graduates in the United States [68]. Similarly, some studies on reading comprehension among DHH university students have reported sixth-grade reading levels among subsets of their samples [4, 51]. Furthermore, prior research has described over 30% of deaf high school graduates in the United States as being “functionally illiterate” [45]. It is important to note that these findings may not be reflective of all DHH adults; those studies also reflect that there are many DHH adults who are excellent readers. Thus, what these studies suggest is that there is great diversity in literacy skills among DHH readers, with a significant subset who face difficulty reading. Prior work in this area has also investigated the particular literacy profile of DHH readers, which is helpful to identify which aspects of reading may pose the greatest challenges. For example, prior work on DHH readers has identified relationships between reading difficulty and syntactic structure for DHH readers [21], as well as other work revealing challenges in identifying changes in context [20]. However, more recent work has identified other sources of difficulty in addition to syntax such as vocabulary knowledge, which seems to also play a role in the diversity of DHH readers’ literacy levels [19, 41]. Similarly, research into reading strategies employed by DHH readers has also identified unfamiliar vocabulary [11, 18, 20] and jargon (e.g., acronyms [20]) as key sources of difficulty. Education research has suggested that early exposure to visual language (such as signed languages) or to written language, using different visual techniques for reading, can lead to higher literacy skills later on [5, 48]. However, considering the research above outlining how many DHH readers may still face challenges in adulthood, ATS-based reading assistance tools may provide a possible solution. This aligns with encouragement from prior work to provide simpler alternatives to textual content in the web [18], as well as to investigate how emerging technologies may support skill development in DHH adults [9]. This context motivates our research into ATS-based reading assistance tools, operating at various linguistic levels, to support DHH readers.

ATS consists of NLP techniques aiming at rewriting the text in a way that improves its readability or understandability while preserving the content from the original text [66]. Thus, it involves identifying complex text, as well generating and selecting appropriate replacements. ATS can operate at the syntactic level (also known as syntactic simplification) by modifying the structure of phrases or sentences to reduce their grammatical complexity; it can also operate at the lexical level (also known as lexical simplification) by replacing complex individual words with simpler synonyms [62]. More recently, researchers have also employed hybrid combinations of both, modifying syntactic structures and replacing individual complex words simultaneously, e.g., [22, 76].

Prior work on using ATS to provide reading assistance for people who are DHH has involved evaluations of benefits obtained from the various simplification approaches described above. For instance, one study identified comprehension benefits from providing syntactic simplification in medical texts [38], while another measured perceived benefits from lexical simplification in science news stories [7]. The latter study also identified that DHH users’ likelihood to use ATS-based reading assistance tools is affected by how much autonomy the system provides to users in terms of being able to control which words are simplified and having visual indications of which words are in a text the technology had already replaced. Prior work has also investigated other approaches to provide linguistic assistance to DHH adults for making information on the web more accessible, such as the use of images or dictionary definitions (in English or ASL) (e.g., [25, 31, 52]). However, no significant improvements in comprehension have been identified from their use [25, 31].

While some prior research on ATS-based reading assistance tools, as outlined in the previous paragraph, have focused on DHH readers [7, 34, 38], there has also been related work on the use of these technologies with other user groups, such as people with dyslexia [54], people with aphasia

[23], non-native speakers [10], people with intellectual disabilities [47], or other low-literacy readers [8, 71]. These works include many user studies focusing on different aspects of the technologies. For example, some user studies focus on evaluating the quality of the output obtained from ATS systems, which typically involve “expert” readers—usually people with native fluency of the language being evaluated—as opposed to the “target” users the tools are intended for (e.g., [30, 57, 73]).

On the other hand, prior work involving specific target user groups have focused on whether users benefit from text simplification at different levels (e.g., syntactic or lexical levels) [7, 38, 44], or on comparing how using different ATS implementations may impact those benefits [55]. Other work has focused on identifying which linguistic properties affect text readability for particular user groups, finding that those properties may not always be the same across different user groups [50, 55]. Furthermore, as described above, some prior work with DHH adults (not necessarily in computing) has investigated some design aspects of the user-interface of ATS-based reading assistance tools that relate to the user autonomy [7]. Finally, while one prior study investigated the user needs and interests of adults with autism in ATS-based reading assistance tools for reading online reviews [74], no prior work has focused on the needs and interests DHH users, nor the more specific context of computing professionals. Thus, in this work, we focus on understanding the general needs and preliminary interest in ATS tools among a specific target user group: DHH adults with experience in the computing field.

2.2 Need for Domain-Specific User Research

ATS research has recently emerged as a sub-field of NLP, and a key challenge in the field has been accessing to training data (e.g., simplification corpora) [62]. As mentioned in the Introduction, one approach that has been proposed to address this challenge is the collection of data sets of judgements from non-native English speakers on the complexity of individual words from a general lexicon, which can be used to train simplification models [42]. Maddela and Xu [42] suggest that it would be useful to gather additional data sets with judgements from other specific user groups or vocabulary on specific domains (e.g., medical, computing, or legal domains). Thus, to construct such data sets with judgements from particular user groups, or within particular domains, it is first necessary to conduct user research into those user groups’ reading habits, reasons for reading, and other details of a particular group of readers in specific domains.

Considering our focus on the needs and interests of DHH users working in the computing field, towards the design of a potential assistive technology in a workplace environment, and the lack of prior work on reading behaviors of DHH individuals in the workplace or their interests for assistive technologies to assist with those reading tasks, we also reviewed research into other assistive technologies for DHH users in the workplace. Most prior work in this area, however, has centered around the use of **Automatic Speech Recognition (ASR)** and captioning. Prior research includes investigations of the use of ASR to facilitate communication with hearing colleagues [24] or customers [43], or how the presence of ASR technologies may affect hearing people’s behavior, which might in turn affect the technology’s performance [60].

2.3 DHH Readers’ Reading Habits

In order to investigate the needs and requirements for ATS-based reading-assistance tools among DHH users in the computing and IT field, it is important to consider what their current reading habits are (i.e., how much reading they do now and what purposes they read for), as well as what tools or workarounds they currently use to support themselves when reading complicated text. When reviewing related work for the latter, we found prior literacy research that has investigated the reading strategies DHH readers used to understand text (e.g., [11, 17, 32, 59]). This prior research has primarily focused on investigating the internal strategies employed by DHH

readers, which include inferential and metacognitive strategies—i.e., strategies that rely on the reader’s own awareness and control of their understanding—such as identifying alternative meanings for individual words, replacing unfamiliar words or phrases with more familiar words or paraphrases, or translating words into **American Sign Language (ASL)** [11]. However, to the best of our knowledge, no prior work has investigated what specific external tools DHH readers employ when encountering the complicated text.

While the prior work above has examined how DHH individuals engage in reading, relatively little work has investigated their general reading habits. The only study we found focusing on the reading habits of DHH individuals, in which researchers compared the reading habits of DHH and hearing university students, found that DHH participants reported reading more often (ranging from six to 56 hours a week) than hearing participants (ranging from one to 43 hours a week) [46]. Furthermore, the most frequent reading activities reported in that study by DHH participants’ involved e-mail and other Internet media [46].

There has been wide diversity in the way reading habits of the general American population (not focusing on DHH individuals) have been measured and reported in prior work. For instance, there are studies that report *a general frequency of reading*, such as a study in which researchers observed that 80% of survey respondents reportedly read occasionally for pleasure and 50% of full-time workers reported reading every day for work or academic purposes [1]. Others, in turn, report the *amount of time spent reading on a day*, including studies in which individuals ages 15–54 reported reading on average 10 minutes per day [2] or which estimate that the general population reads an average of 15.6 minutes per day [72]). This diversity is also present in what the focus of their investigations are. For instance, while some prior work compared people’s reading frequency between different purposes for reading, including a comparison between work or academic purposes and leisure (e.g., [33, 37]), others have focused on leisure alone (e.g., [2, 29]), or books (e.g., [77]). Other studies have focused on the relationship between participants’ demographic factors and their reading habits, including factors such as race (e.g., [58]), reading proficiency (e.g., [63]), or levels of education and occupation (e.g., [37, 67]).

However, these findings—for DHH readers or Americans in general—may not generalize to DHH workers, let alone in a specific field, for prior research on the general population has found that not only the “setting” (i.e., work vs. leisure), but also an individual’s occupation affected their reading habits [37]. Thus, the authors of that study suggest, when investigating the reading habits of a particular user group, it is important to consider the contexts and settings of interest in which reading may occur, as well as readers’ characteristics and reading habits. To the best of our knowledge, however, no prior work has investigated the contexts and settings of interests for reading, nor the reading practices of DHH individuals in the computing industry. Thus, in this work, as we investigate these individuals’ needs and interests in ATS-based reading assistance tools, we also examine their reading habits and contexts of interest to them, and in which of these contexts users would be interested in having ATS-based reading assistance.

2.4 Social Accessibility

Finally, as we investigate preliminary interests in potential assistive technologies for the workplace, it is important to consider related work on the social accessibility of assistive technologies as encouraged by recent work in the area [65]. Social accessibility, a term defined in [65], is used to distinguish the social aspects of assistive technologies from their functional aspects. In this sense, the term social accessibility encompasses the understanding of perceptions of assistive technologies in social contexts as they relate to users’ social identities and how their abilities are portrayed. Many research studies have focused on one aspect of social accessibility, social acceptability, which in the context of social accessibility relates to perceptions of the appropriateness of using assistive

technologies in social environments, and it involves tensions between users' aspirations or fears, and social norms or onlooker's perceptions [36].

Prior work has established that social influences have significant effects in personal adoption of technologies when their use is mandatory (as opposed to voluntary) for users without disabilities [69]. However, the most closely related work to our present work lies in studies of social acceptability in the context of users with sensory disabilities, where the choice of use of a particular assistive technology may not necessarily be mandatory, but intended to provide access and may involve social stigmas [65].

Research with users with different sensory disabilities has found that *well-functioning* assistive technologies enable greater feelings of independence and self-efficacy [40, 65]. However, research has also identified bystanders' misperceptions of assistive technologies, which include beliefs that assistive technologies eliminate someone's disability, or that users with a disability cannot do anything without their assistive technologies [64]. These misperceptions, especially when a device malfunctions, can also lead to ambiguities around the users' abilities, such as the bystander concluding that users are incompetent or not capable of doing tasks that they are actually able to do [64]. Those ambiguities, along with potential breakdowns or malfunctions of the assistive technologies, can cause negative feelings, such as self-consciousness (i.e., an uncomfortable awareness of oneself as being observed by others) [64].

In the context of DHH users, prior work on the social acceptability of assistive technologies has focused on devices such as wearables for accessing spoken or auditory information [26], finding that users' perceptions of the social acceptability of wearable sound-awareness devices were most affected by the context of use [26]. Other research into similar devices has found that whether technologies are framed as *assistive* also influences onlookers' perceptions of their social acceptability [53], while other work with users with disabilities in general identified that designing assistive devices resembling mainstream devices may also help in mitigating social acceptability issues [64].

The prior work with DHH users outlined above, however, focused mostly on the use of assistive *devices* (e.g., [26, 53]), as opposed to software tools that may be used within already-mainstream devices. Thus, while their results regarding the sources for social accessibility issues as well as potential solutions to mitigate those may be informative, they may not generalize directly to assistive *software*, such as ATS-based reading assistance tools. Also, considering that many members of Deaf culture do not consider deafness a disability, but a cultural difference instead, the social accessibility of assistive technologies relating to language may involve nuanced tensions not present in other contexts, and other perceptions (or misperceptions) in addition to those identified in [64] may be at play. However, to the best of our knowledge, issues of social accessibility of ATS-based reading assistance tools, such as what kinds of feelings they may generate among users or what aspects can affect their social acceptability, have not been explored among DHH adults (or any user group), let alone in a workplace context. Thus, considering encouragement from prior work for researchers to consider these issues early in the design of new assistive technologies [39, 65], in this work, we also explore the perceptions of DHH adults with experience in the computing industry towards the acceptability of ATS-based reading assistance tools from a social accessibility perspective.

2.5 Research Questions

Given the context of this prior work, we investigate the following research questions:

- What are the reading practices of DHH individuals with work experience in the computing industry? More specifically, how much reading are they doing, how are they reading (i.e., on a screen or article-based), and what are they reading for?

- How much do DHH individuals in the computing industry engage in reading for learning about new topics at work?
- What are the views of DHH individuals in the computing industry about their experience with complicated text, and how do they overcome it?
- Are DHH individuals in the computing field interested in ATS-based reading assistance tools? And if so, for which reading activities would they be interested in it for?
- What are the perceptions of DHH individuals with experience in the computing field on the social accessibility of ATS-based reading assistance tools? How can these tools be better designed to address potential issues of social accessibility?

3 STUDY 1: READING EXPERIENCES AND INTERESTS IN TOOLS

To investigate domain-based user needs for reading assistance tools based on ATS, we conducted a mixed-method study including pilot interviews, an online survey, and follow-up interviews with DHH individuals who have had experience in the computing and IT fields. The pilot interviews ($N = 12$) informed the design of the online survey ($N = 32$), and the follow-up interviews with a subset of survey respondents ($N = 5$) provided a deeper understanding of the patterns that had emerged from in survey results. In this section, we present the methods for each phase of this study.

3.1 Pilot Interviews

To inform the design and terminology used in our survey study, we first conducted pilot interviews with 12 DHH participants. In these interviews, we explained the concept of ATS-based reading assistance tools and asked them questions about situations in which they could envision using (or not using) such tools, as well as what they currently do when they encounter text they could not understand. This data allowed us to pilot-test the language we would later use for video demonstrations of the tool, as well as gather lists of reading purposes and workarounds to overcome complicated text, which we could use when preparing answer-choice options for similar items in the questionnaire for our survey (Section 4.2). A total of 12 DHH participants were recruited through e-mail and social media. Participants self-identified as male ($N = 7$) and female ($N = 5$), with mean age of 24 ($SD = 1.5$). There were eight participants who identified as culturally Deaf [49], three as hard-of-hearing, and one as deaf. Participants met in person with a research assistant and the interviews were conducted in English or ASL at the participants' preference. Participants were compensated with \$40 for their participation. The analysis of these pilot interviews was primarily formative: Specifically, any interview questions that had required clarification during pilot interviews were edited for clarity when authoring related items on the survey questionnaire (Section 4.2.2), and the open-ended responses from pilot study participants informed the list of answer choices for some questionnaire items. Full details of the survey questionnaire appear in Section 4.2.2.

3.2 Survey

3.2.1 Participants. Our participant-selection criteria included identifying as DHH, as well as having had work experience (including internships) in the computing or IT within the past five years. Participants were recruited through social media posts, e-mail advertisements, and word of mouth, through the career center and alumni networks at our institution, as well as colleagues at tech companies and computing accessibility groups. Participants were offered the opportunity to enter into a raffle to win a \$100 gift card.

We received a total of 32 responses (an additional 17 started, but did not complete it, yielding a dropout rate of 34%). Participants' mean age was 28.3 ($SD = 7.9$), ranging from 20 to 54. Participants self-identified as male ($N = 18$), female ($N = 13$), and agender ($N = 1$). The highest degrees obtained

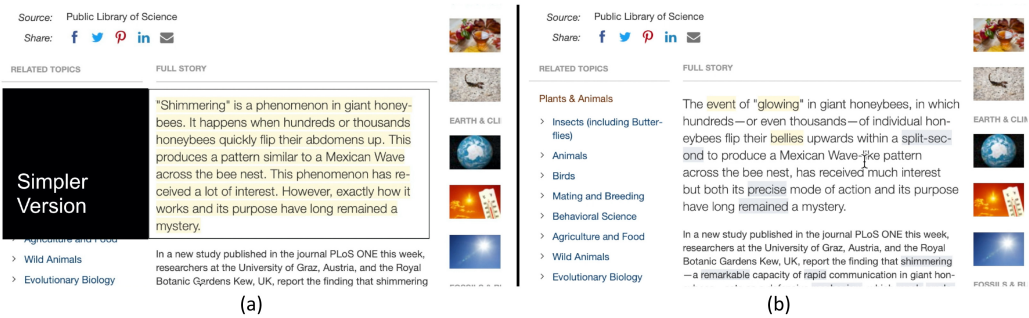


Fig. 1. Screenshots from the video demonstration shown to participants in the survey and follow-up interviews demonstrating (a) syntactic simplification and (b) lexical simplification.

by participants included high school ($N = 4$), associate's¹ ($N = 9$), bachelor's ($N = 13$) and master's ($N = 6$), with 17 out of 32 participants indicating they were still students. Participants had an average of 5.5 years of work experience in the computing field ($SD = 7.37$), ranging from less than a year to 32 years. There were eight participants who identified as deaf, 10 as hard-of-hearing, 12 as culturally Deaf [49],² and two as "other" (one indicated being "deaf with cochlear implants in both ears," and one as being "deaf in only one ear, but hard-of-hearing on the other"). In terms of communication preferences, there were six participants who preferred spoken language only; seven who indicated mostly spoken language, with a little sign language; six who preferred about half of each; six who preferred mostly sign language, with a little spoken language; and six who preferred only sign language. Lastly, most participants reported feeling very comfortable with reading English ($N = 18$), while others indicated feeling comfortable ($N = 8$), neutral ($N = 5$), and not comfortable ($N = 1$).

3.2.2 Materials and Procedure. The survey, hosted using Qualtrics, consisted of 30 questions, and it required approximately 15 minutes to complete. As per our IRB protocol, participants answered this survey privately and anonymously as the link was shared with them to fill out on their own. Most of the questions were Likert-type items on a 5-point scale or multiple-select questions (in which a participant could select more than one option among a set of choices presented). The questions were grouped by the following topics: (1) participants' reading habits and their practices for learning on their own at work; (2) their experiences encountering difficult text and the workarounds used to overcome it; (3) their interest in ATS-based reading assistance tools in general and for specific activities that may involve reading; and (4) their thoughts on issues of autonomy and social acceptability in the context of the design of such tools. Before answering questions about ATS tools (group "3" of questions, as listed above), participants were shown a brief video demonstrating a reading-simplification tool, including examples of both lexical and syntactic simplification. As ATS tools are not yet widely available to consumers, we created this video demonstration following the style of recent user research on ATS which included preliminary work into the visual design of such systems [7]. Figure 1 shows screenshots of this video demonstration, and the original video is shared as an electronic appendix with this article—along with a complete copy of our survey questionnaire.

¹In the United States, an associate's degree is an undergraduate degree awarded after two or three years which is higher than a high school diploma, but below a bachelor's degree.

²The term "Deaf," with a capital D, refers to people who identify as members of Deaf culture, while "deaf" and "hard-of-hearing" usually refer to different degrees of the conditions of deafness and hearing loss [49].

3.2.3 Data Analysis. We calculated descriptive statistics (e.g., median, quartiles) for our ordinal scale data, as well as frequencies for data obtained from multiple-select questions. Furthermore, since our scalar-response data were not normally distributed, we conducted non-parametric statistical tests for difference testing, including Friedman and Kruskal–Wallis tests. Similarly, for correlation analysis, e.g., between a user’s communication preference and their interest in the ATS tool in different contexts, Spearman correlation analysis was performed for this non-parametric data.

3.3 Follow-up Interviews

The final question in our survey asked participants if they would be willing to participate in a follow-up interview study, which we conducted with a subset of our survey respondents who expressed a willingness to participate. Before presenting the survey results, we present here our methods for this interview portion of our first study. Afterward, we will provide a combined results section of both the survey and the interview results, in an interleaved manner.

3.3.1 Materials. These semi-structured interviews consisted of 30 questions, and they were grouped in similar categories as those of the survey, except in this case the categories were more open-ended in nature. The first category was about reading, which included questions about which activities participants read for, what they enjoy and do not enjoy reading about, as well as what they enjoy or do not enjoy about the activity of reading itself. We then asked participants about how they learn in the context of work, and how reading compares to other activities such as watching videos. Then, we asked participants about facing the complicated text, what they believe affects someone’s reading skills and text difficulty, as well as how they personally try to understand complicated text. Questions about difficulty in reading were first posed in the third-person, due to the sometimes-sensitive nature of asking about literacy difficulty, under the assumption that respondents may be more willing to share their personal experiences after grounding it amid that of others. Finally, we showed participants the same video shown in the survey again and asked them questions such as the positive and negative impacts they could imagine the tool could have, as well as how they would feel if they either saw or were seen by co-workers using such tools. The full list of questions is shared as part of an electronic appendix.

3.3.2 Procedure. A total of seven participants who had responded “yes” to whether they would be willing to participate in interviews were randomly selected and contacted via e-mail, and five of these individuals responded to this request for an interview appointment. These five interviews were conducted using video-conferencing because of social-distancing restrictions due to COVID-19. Participants were provided with informed consent forms ahead of the interview via e-mail. All of the interviews were conducted via video-call using Zoom and lasted 35 minutes on average, and were recorded for later reference with the participants’ consent. Four of the interviews were conducted in ASL by a researcher in the team who is hard of hearing and fluent in ASL, and one was conducted in English using the chat feature on Zoom. At the end of the interview, participants privately filled out an anonymous demographics form which included questions about their communication preferences and comfort in reading English. Participants were compensated with \$40 for their participation.

3.3.3 Participants. Participants’ mean age was 28 ($SD = 4.5$), ranging from 27 to 37. Participants self-identified as female ($N = 3$) and male ($N = 2$). The highest degrees obtained by participants included associate’s ($N = 1$), bachelor’s ($N = 3$), and master’s ($N = 1$), with three participants indicating they were still students. Participants had, on average, 3.8 years of experience working in the computing field ($SD = 1.48$), ranging from 2 to 6. There were three participants who identified as deaf, while the other two identified as culturally Deaf. In terms of communication preferences, one participant indicated preferring mostly spoken language, two participants who preferred about

half of each, but mostly sign language; and two preferred only sign language, one of which also specified preferring “written language.” Lastly, one participant reported feeling very comfortable with reading English, another one indicated feeling comfortable, two neutral, and one not comfortable.

3.3.4 Data and Analysis. Of our five interviews, four had been conducted in ASL, and these were interpreted and transcribed by a researcher who identifies as hard of hearing and is fluent in ASL. Those four interviews amounted to a total of 119 minutes of video recording. Together with the fifth interview, conducted through chat, there were a total of 5,100 words of transcripts. These transcripts were analyzed by one researcher in the team using an inductive coding process with axial coding.

4 STUDY 1: RESULTS

In this section, we present the results of our first study, which included the survey and the follow-up interviews. Based on the results from both studies, our findings are grouped into five categories: (1) our participants’ reading frequencies and activities; (2) learning in the context of work; (3) participants’ perceptions of complicated text and workarounds to overcome it; (4) participants’ interest in ATS-based reading assistance tools; and (5) design considerations for such tools.

4.1 Reading

4.1.1 Reading Frequency. We asked participants in the survey to report their general frequency of reading (without specifying purposes yet) using the question “In general, how often do you read.” Following the methodology of [37], participants responded on a 5-point scale of: “rarely (less than once a month),” “monthly (one to three times a month),” “weekly (once a week),” “often (two to four times a week),” and “daily (five or more times a week).” The majority of survey respondents reported reading at least once a week, including 16 who reported reading daily and seven who reported reading two to three times a week. Another three participants reported reading one to three times a month, while five reported reading less than once a month. Similarly, four of the interview participants indicated reading often, except for P4, who indicated “not reading as often as I would like.” When comparing the reading frequency responses on this question to response data on similar types of questions collected from among the general United States population in prior work (as discussed in Section 2.3), our participants’ frequency of reading was relatively similar.

4.1.2 Reading on an Electronic Screen. Survey participants next estimated the number of minutes spent reading, on a day that they read. However, in order to investigate how much of their reading happens on a screen (where ATS-based reading assistance tools are typically deployed), we asked for this estimate in two separate questions: how many minutes a day spent reading on a screen (e.g., computers, laptops, phones, tablets) and not on a screen (e.g., books, magazines, newspapers, print-outs). As illustrated in Figure 2, 25 survey respondents reported reading over 30 minutes a day on a screen, 15 of which reported reading over 60 minutes a day on a screen. In comparison, most survey respondents ($N = 21$) reported reading text not on a screen less than 15 minutes a day, with seven indicating spending no time at all. A Wilcoxon signed-rank test indicated a significant difference between the reported time reading on a screen and not on a screen ($p < 0.01$).

The data from the interviews showed a similar trend, with three out of five participants explicitly saying that they tend to read more “online,” or in the words of P5, “I read mostly on the computer.” Some of the sources for content online cited by participants included blogs on platforms such as “Medium,” forums on platforms like “Reddit,” as well as online newspapers and social media.

4.1.3 Purposes for Reading. Given that we had asked participants about their overall reading frequency without specifying purposes, we then asked participants in the survey about the

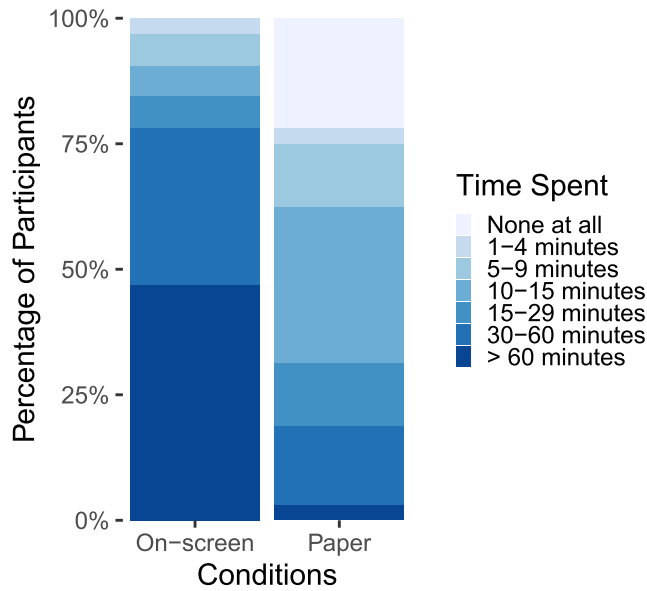


Fig. 2. Participants' responses to the questions: On a day that you read, how much time do you spend reading text (a) on a screen (e.g., computers, laptops, phones, tablets) and (b) that is not on a screen (e.g., books, magazines, newspapers, print-outs). There was a significant difference between the two ($p < 0.01$).

purposes for which they read. Participants responded by selecting as many items as they wish from among the following list, which was obtained from our pilot interviews (Section 4.1): work (e.g., technical text), academic (e.g., research articles, scientific articles, class, exams, textbooks), medical (e.g., health insurance, diagnosis), legal (e.g., terms of service, contracts), personal communication (e.g., e-mail, text messages, social networks), visual media (e.g., movies, tv shows),³ personal reading (e.g., books), recreation (e.g., restaurant menus), and news (e.g., newspapers, magazines). Finally, a write-in "other" option was provided so they could mention other purposes for reading. Work was the purpose that survey respondents reported most often ($N = 29$), with academic ($N = 26$), personal communication ($N = 25$), and visual media ($N = 24$) coming close behind. The least selected options were medical and legal, with eight respondents each. Figure 3 summarizes the frequencies for all options.

Interview participants drew distinctions between "personal reading" as compared to reading for work or academic purposes. Two interviewees reported mainly reading for work (P1 and P4), with P1 commenting: "With regarding to reading (online), I use for work stuffs and learning things to improve my career (programming for example)." Another two interviewees mentioned reading for academic purposes, with P2 conditioning her frequency of reading on whether she is at school, saying, "If I'm in school I tend to read weekly almost every day." All interview participants, in turn, mentioned different forms of personal reading out of interest or curiosity, such as reading "storybooks to enjoy" (P1), or "technology, bible, something that interests my curiosity like martial arts" (P4). Two other participants mentioned being motivated to read to be aware of what is going on in the world, e.g., with P3 commenting "since this situation (COVID-19) we have to read emails, social media every day, all day." Finally, two participants also specified that, for personal reading,

³This was identified as a reading activity during our pilot study, given that many participants read captions when watching visual media.

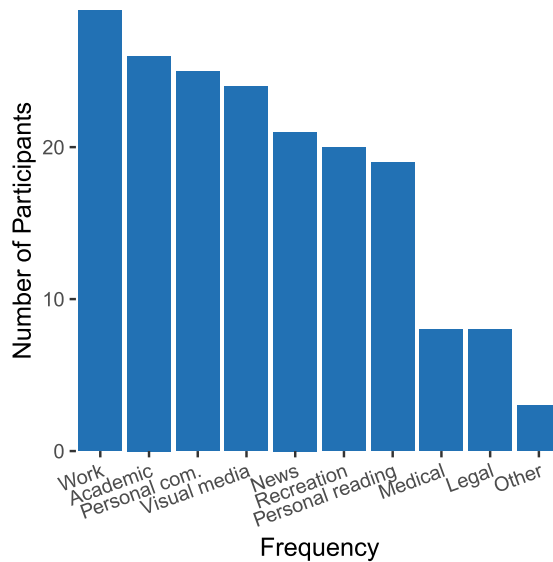


Fig. 3. Counts for responses to the different reading purposes included as options for the question “For what purposes do you read? (select that apply).”

they prefer reading content such as stories “with simpler words” (P2) or “that are simple like thriller novels and not like Shakespeare” (P1).

4.2 Learning for Work

In order to further understand the importance of reading in the context of work, the survey asked participants to rate how often they read to learn about technical topics at work, as well as how often they watched videos for the same purpose. The rationale for including this question about watching videos is the increasing prevalence of online viewership [13], as well as using this set of two questions to help further quantify the amount of reading these users engage in (by comparing it to frequency responses they provide for some other activity, namely watching videos). Both of these questions were on the same 5-point scale used for the general reading frequency above, going from rarely to daily. As shown in Figure 4, the majority of survey respondents ($N = 23$) reported reading at least once a week for learning about new topics at work, nine of which reported doing so two to three times a week, and another 9, daily. The majority of participants ($N = 18$) also reported watching videos to learn about new topics at work at least once a week, with nine reporting doing so two to three times a week, and 3, daily. A Wilcoxon signed-rank test indicated a significant difference between the reported time reading and watching videos to learn about technical topics at work ($p = 0.037$).

We asked about similar topics in our interviews. There were idiosyncratic differences in terms of whether interview participants preferred reading vs. watching videos overall, with two participants explicitly saying they prefer videos in general, one saying they typically prefer reading, and one rather simply stating it “depends on my mood” (P5). However, when talking about specific situations in which they would prefer one or the other, most participants indicated preferring videos for learning new things, topics that are unfamiliar, that are practical, or in the words of P4 “when not a lot of thinking is required.” Participants indicated preferring reading over videos when they are already familiar with or passionate about topics, or when they are reading concepts that are more technical in nature or that are “hard to memorize” (P1).

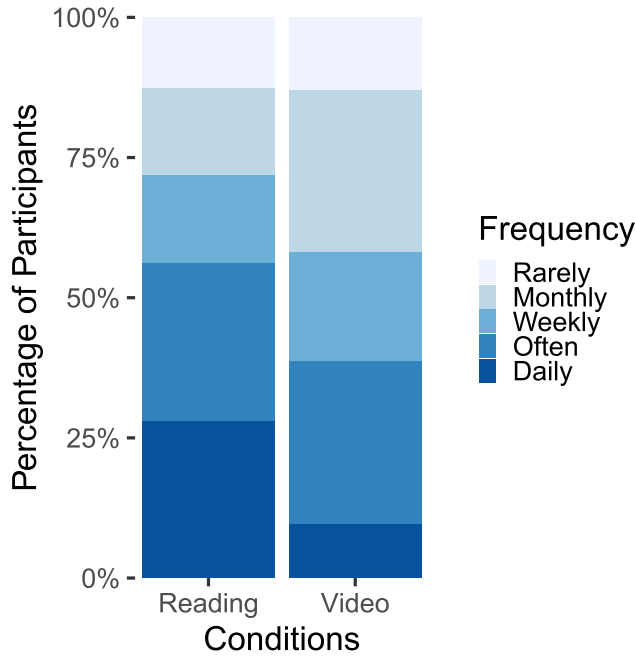


Fig. 4. Participants' responses to the questions: "How often do you read to learn about technical topics for your work (e.g., information about new technologies, new software, programming information)?" and "How often do you watch videos to learn about technical topics for your work (e.g., information about new technologies, new software, programming information)?" The full text in the options was: "rarely (less than once a month)," "monthly (one to three times a month)," "weekly (once a week)," "often (two to four times a week)," and "daily (five or more times a week)." There was a significant difference between the two ($p < 0.05$).

4.3 Complicated Text

The survey asked participants to rate "how often do you encounter a text that is complicated" on a 5-point scale from "Never" to "Very often". There was a wide range of responses to this question: The median response was "neither seldom nor often" (14 participants). The lower quartile response was "seldom" (8 participants), while the upper quartile was "often" (9 participants).

Interview participants indicated text being "hard to read" is something that they do not enjoy about reading. For example, in the words of P2, "I don't like to read theory related readings because they're too hard to read."

Two participants (P1 and P3) used Shakespeare's as their examples of what complicated text looks like, with P1 specifically mentioning Shakespeare text as something she does not like to read. When discussing what makes a text complicated, all interview participants mentioned vocabulary or terminology that they are unfamiliar with as one of the main sources of difficulty. As P4 put it: "Because sometimes you are reading and understanding, but all of a sudden there's a word that makes you lose your train of thought. You have to stop there, analyze what it means, look it up and then look at the reading to figure out where you left off to continue reading." Furthermore, three participants associated negative feelings with complicated text, two of which mentioned feeling frustration (P4 and P5), and P2, a loss of confidence: "I felt pressured to use that same level of English [as my classmate], so it takes me more time to read and write. I really didn't like that pressure. It also caused me to lose confidence in class. There is a lot of discussion in class and I would feel like my classmates were smarter than me." Finally, some participants seemed to quantify

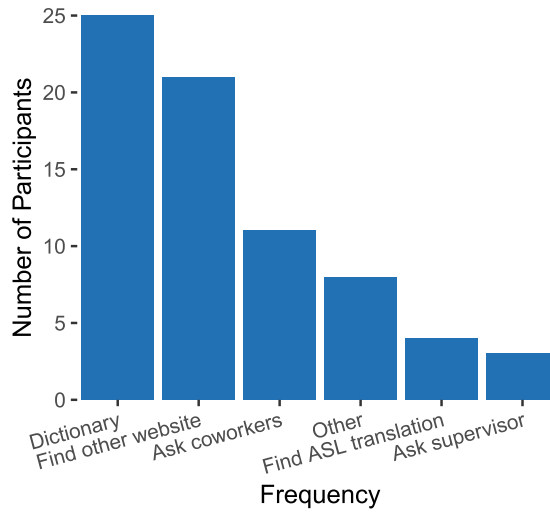


Fig. 5. Counts for responses to the different reading purposes included as options for the question “How do you try to understand text that is complicated? (select all that apply).”

complicated text in terms of the time it adds to reading. P5, for example, stated that “I consume so much time trying to figure out what a word means. Then, once I figure it out, I continue to read.”

4.3.1 Overcoming Complicated Text. Our survey participants were also asked to indicate resources they typically use to try to understand text that is complicated, selecting as many items they wish from the following list: a dictionary, looking for a translation to ASL, asking coworkers for help, asking a supervisor for help, and looking for other websites talking about the same topic. Finally, a write-in “other” option and “this doesn’t apply to me” were provided. The composition of answer choice options on this list was informed by several sources, including our pilot interviews (discussed in Section 3.1) as well as considering whether there exist external tools analogous to internal metacognitive strategies employed by DHH readers who encounter complex text [11]. As shown in Figure 5, the most frequently selected response was looking up words in a dictionary ($N = 25$), followed by looking for other websites talking about the same topic ($N = 21$). The least frequently selected options were looking for a translation to ASL ($N = 4$) and asking a supervisor for help ($N = 3$).

In our interview study, “looking up” words was mentioned by all interview participants as a way to overcome complicated text. Notably, at least three participants specified that these “look-ups” may consist a Google web search for the word, rather than using a specific dictionary resource. As P4 said: “If I have dictionary, I use it or just do a quick research on Google.” Furthermore, four participants mentioned asking others for help, including friends, interpreters, co-workers, supervisors and professors. P3 indicated that her asking someone else for clarification depends “on where I am and my surroundings.” Notably, P1 mentioned trying to understand some text first before asking others, especially more senior colleagues, because “I hate to ask “bigger” people since it brings embarrassment to me.”

4.4 Interest in Tool

We showed participants a video demonstration of a prototype ATS-based reading assistance tools, using the two most common approaches in the ATS literature: lexical and syntactic simplification.

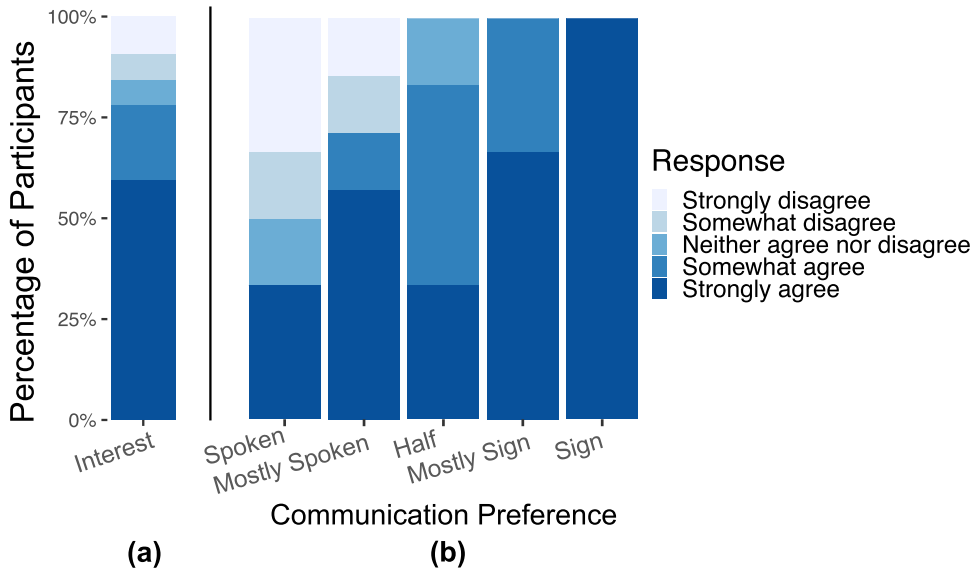


Fig. 6. Participants' agreement to a Likert-scale question "I would be interested in a tool that helps me to understand text by making it simpler" (a) overall and (b) broken down by communication preferences. Communication preference levels: Spoken = "Spoken language only", Mostly Spoken = "Mostly spoken language, with a little sign language", Half = "About half-spoken language, half sign language", Mostly Sign = "Mostly sign language, with a little spoken language", and Sign = "Sign language only".

The video was approximately two minutes long and included demonstrations of using the tool for both of these approaches; a copy of this video is included as an electronic supplementary file with this article. We then asked participants to indicate their agreement to the statement "I would be interested in a tool that helps me to understand text by making it simpler" on a 5-point Likert scale from "strongly disagree" to "strongly agree." As illustrated in Figure 6(a), the overall response was positive, with a median answer of "strongly agree," with 25 participants responding at least "somewhat agree," out of which 19 responded, "strongly agree."

In our interview study, the same video demonstration were shown to all five participants. All indicated that the main benefit they envision an ATS tool would provide would be saving them time. As P1 put it, "It would speed up my reading pace that is all-important." Three participants also mentioned not having to ask others for help or clarification as a benefit of the tool. P2, for example, stated "It would help us to read easily without asking others to help." Other benefits mentioned by participants included learning new words (P2 and P4), as well as reducing frustration (P5) and increasing confidence (P1). Three participants explicitly mentioned that the benefits would not be limited to DHH readers, but also, as P1 put it, "hard readers (Deaf and other disabilities and non-English speaking)."

4.4.1 Tool Interest and Communication Preference. Considering that prior work with DHH users in other domains (e.g., sound-awareness technologies [26] or sign language animations [35]) has identified that users' communication preferences (i.e., sign-language vs. spoken) may influence their interest in or opinions on certain technologies, we wanted to investigate whether that was the case here as well. Survey participants' response to the question about communication preference was coded using a scale 1 (spoken); 2 (mostly spoken, some sign); 3 (half and half); 4 (mostly sign, some spoken), and 5 (sign). A Spearman correlation test revealed a significant correlation between

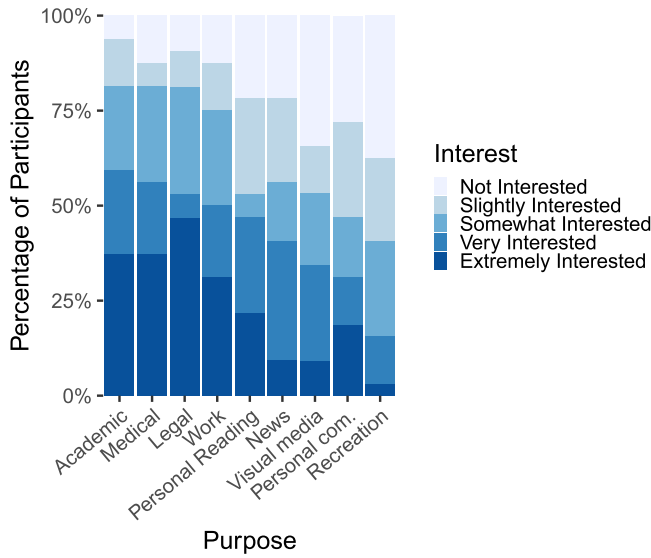


Fig. 7. Participants' Likert-scale responses to the question "Please choose your interest in a tool like the one in the video for each activity below."

users' reported communication preference and their interest in the tool ($\rho: 0.5, p = 0.0034$), with participants who preferred sign language reporting higher interest in the tool, as illustrated in Figure 6(b). A Kruskal–Wallis test, however, did not reveal any significant difference between the groups.

In our interview study, when participants talked about issues that affect people's reading levels and their perception of difficult text, all participants mentioned English not being their first language: "I struggled and it was hard for me to pick it up, and for Deaf people ASL is their first language, and English is not their first language. ASL is completely different" (P5). Furthermore, participants talked about people's upbringing or exposure to English—either by listening or reading—as another source of difficulty. P3, who identified as a strong reader, said "I am from a 5th generation Deaf family, but my grandma was strict with English and forced me to learn English all of my life. I am grateful for her, so really the main point is the people in your life and how involved they are and how they empower you." Thus, our question related to "communication preference" may have correlated with interest in the tool because it may have shed some light as for which language participants feel more confident with.

4.4.2 Tool Interest and Purposes for Reading. Survey participants were also asked whether they would be interested in a tool like the one in the video for each of the purposes for reading (the same list we had provided previously in the Reading Habits section), using a 5-point Likert-type question from "Not Interested" to "Extremely Interested". A Friedman test did not indicate a significant difference between the responses when comparing the various purposes for reading. Figure 7 indicates that the responses that received the most "extremely" or "very" interested responses from our respondents were: academic, medical, legal, and work.

In our interview study, while all participants mentioned they would personally use the tool, four mentioned they would not use it for texts that are written informally or using "basic English." As P1 commented, "Any content that are already in basic English or written in informal talking style [the tool] isn't needed." These comments suggest that participants' interest in using the tool

when reading for various purposes may be related to their estimate of how likely they would be to encounter complex English text when reading for that purpose.

4.5 Design Considerations

4.5.1 Autonomy. Recent work on the design of ATS-based reading assistance tools for people who are DHH identified autonomy as a design aspect that may affect acceptability of such tools [7]. In that prior work, autonomy had been framed as whether the tool gave the user control over which texts were simplified (vs. doing so automatically) and whether the system made it clear whether the user was looking at an original or a simplified version of some text. Thus, in our survey study, participants were asked to imagine using such a tool (after viewing the video demonstration) and to respond to two questions related to the autonomy the tool would provide: “I would be upset if the tool replaced text before I got to see it” and “I would be upset if the tool replaced text without asking me.” The majority of survey respondents reported they would be upset if the tool replaced text before they got to see it, and also that they would be upset if the tool replaced text without asking them, with median agreement responses of “strongly agree” for both question items, and more than 75% of respondents responding at least “somewhat agree.”

In our interview study, we did not ask about autonomy directly given that prior work at our laboratory had focused exclusively on issues of autonomy [7]. However, one participant mentioned it as an expectation: “When the website loads, I don’t expect to immediately translate. It is unto the people’s preference to choose to switch if they like” (P1). However, two participants brought up a related issue: P3 highlighted as a downside of the tool that there would be “additional clicking to do.” P1, in turn, suggested that “Since the system works on sections rather than the whole paragraphs, it requires switching every paragraph which is complicated. I would like if the whole website translates the content to “simple language.”” These comments relate to a specific aspect of autonomy in the design of user interfaces for these tools: how much text is replaced at once upon the users’ request.

4.5.2 Accuracy. A topic we did not specifically ask about in a question in the survey, but which several participants mentioned during interviews was that the accuracy of the tool was a key concern of these users. More specifically, the possibility of the tool “causing people to misunderstand the word if it’s not the right meaning or replacement word” (P2), or as P3 put it: “Maybe the tool could misinterpret the word. The wording in the sentence could mean one thing while the tool may interpret it to something else. Whatever the coding or something could misunderstand the true intent of the sentence.”

However, when asked about how the perceptions of the system would change if the system was not 100% accurate, interview participants reported they would think the tool is still useful if the tool meets a certain threshold of accuracy, with two participants estimating that threshold to be “90%.”

4.5.3 Social Acceptability. Finally, considering issues of social accessibility in assistive technology design [65], focusing specifically participant’s perceptions of their social acceptability, we also asked participants to rate whether they would be embarrassed if a colleague saw them using a tool like the one in the video, which may shed light into whether the visibility of such a tool should be further investigated. The majority of survey respondents responded either “somewhat disagree” or “neither agree nor disagree,” with a median response of 2.5 (between “somewhat disagree” and “neither agree nor disagree”).

When looking at the interview data, however, three interview participants indicated that the social acceptability of the tool may be dependent upon the environment, specifically on co-workers understanding of the users’ situation. As P2 puts it: “I would feel ashamed. If we all have the same problem with English then I would be fine but if people whose first language is English, they

probably wouldn't understand why or look down upon or judge me so I wouldn't want to use it in that environment." P5, in turn, expected some judgment from co-workers: "Maybe they would think he's really on a tool? Or be impressed because I'm using a tool as an effort." On the other hand, P4 thought that it was "not about how I feel if it helps me then why not," or P1 who thought personal values were more important than what co-workers think: "I don't mind either too [if a co-worker uses it]. I care that the information should be readable and accessible."

Given this discrepancy between the survey and interview results, we decided to further investigate the social acceptability of these tools from a social accessibility perspective in a follow-up study, which is described in the next section.

5 STUDY 2: SOCIAL ACCESSIBILITY

Based on our results from our survey and interview, we wanted to further investigate one of the design considerations outlined above, namely the social accessibility of the tools, given the inconclusive results from our survey and interview results. Thus, we conducted a follow-up interview study with seven participants in which we focused only on issues related to social accessibility specifically in the work context, which include participants' personal values in a professional context (e.g., how they want to be seen by their colleagues) and how those may relate to using ATS-based reading assistance tools. Further, we investigate how they perceive the use of these tools, as well as how they would expect their colleagues to perceive it, and how those expectations may affect their view of the social acceptability of using ATS-based reading assistance tools in the workplace.

5.1 Method

5.1.1 Materials. The questionnaire for these semi-structured interviews consisted of 20 open-ended questions, which were grouped into four sections. In the first section, we asked participants about their work experiences (e.g., what type of work they do and how long they have done it for), as well as their reading experiences (e.g., how much they read and what they like to read), as a way to get them grounded on these experiences for our later questions in which we would ask them to imagine using reading assistance tools in a workplace environment. We then asked participants questions about what they value at work and how they want to be perceived by their colleagues in a professional environment. Then, we asked participants more specific questions about reading and reading skills, which included questions about how they would describe the diversity in literacy among DHH readers, as well as whether they personally use tools to support their reading tasks. Finally, after showing participants the same video demonstration used in the survey and the previous sets of interviews, we asked participants more directly about their perceptions of using ATS-based reading assistance tools both from a personal and a social perspective. On the personal perspective, we first asked them questions about what they thought about the tool. Because we had observed some people express some reservations about the label "simplification" in our pilot interviews described in Section 3.1, we also asked them about their thoughts on those tools being called "simplification" tools and, if they were not hesitant themselves, why they thought some people may be hesitant to use a tool with such a name, as well as what alternative names they thought may help mitigate that hesitancy. On the social perspective, our questions included what they would expect others to think if they were seen using ATS-based reading assistance tools as well as how they themselves would feel if others saw them. Because in the results from our first study, as described in Section 4.5.3, some participants expressed they might feel embarrassment, in these interviews we asked participants why they thought someone would feel embarrassed if seen using these types of tools, if they would not feel so themselves. Finally, we also asked participants for ways that could help mitigate that embarrassment. The full interview questionnaire for this set of interviews is also included as part of our electronic appendix.

5.1.2 Procedure. We reached out to 13 survey respondents who had indicated willingness to participate in follow-up interviews but had not participated in our previous set of interviews, and two of them participated in this new set of interviews. We recruited another five participants through posting advertisements in social media groups of DHH users, for a total of seven participants. Participants were provided with informed consent forms ahead of the interview via e-mail, and met with a researcher via video-call using Zoom. The interviews lasted 35 minutes on average, and were recorded for later reference and transcription, with the participants' consent. Two of the interviews were conducted in ASL by a researcher on the team who is hard of hearing and fluent in ASL, and the rest were conducted in English using professional captioners. Similar to our previous set of interviews, at the end of the interview, participants privately filled out an anonymous demographics form which included questions about their communication preferences and comfort in reading English. Participants in this study were also compensated with \$40 for their participation.

5.1.3 Participants. Participants' mean age was 34 (SD = 12.7), ranging from 21 to 55. Participants self-identified as female (N = 3), male (N = 2), agender (N = 1) and non-binary (N = 1). The highest degrees obtained by participants included high school (N = 2), bachelor's (N = 3) and master's (N = 2), with three participants indicating they were still students. Participants had an average of 10.6 years of experience in the computing field (SD = 10.6), ranging from less than one year to 30. There were two participants who identified as deaf, four who identified as hard-of-hearing, one who identified as both deaf and hard-of-hearing, and one who identified as culturally Deaf [49]. In terms of communication preferences, three participants preferred spoken language only, one participant preferred spoken language with a little sign language, two participants who preferred about half of each, and one preferred mostly sign language, with a little spoken language. Lastly, five participants reported feeling very comfortable with reading English, and another two indicated feeling comfortable.

5.1.4 Data Analysis. Our seven interviews yielded 245 minutes of recordings. The interviews conducted in ASL were transcribed by the research assistant in our team who conducted the interviews, and for those that were conducted using professional captioners, the captions provided were saved after the interviews. Combined, these transcriptions amounted to a total of 19,293 words.

This data was then analyzed by three researchers in our team using a thematic analysis approach as described in [16] by first doing a round of open coding independently and identifying categories of codes, followed by a few rounds of discussion to refine the codes and identify themes from the data.

6 STUDY 2: RESULTS

After conducting a thematic analysis on our data, we identified four key themes related to our research question. First, we found that participants described wanting to be seen by others in their workplace as competent and reliable, and these perceptions are important to them, especially so in a workplace or academic setting. Second, participants described a potential perceived relationship between literacy skills and cognitive ability or intelligence. Thus, being seen using an ATS tool, which may imply literacy issues, could come in conflict with their desired image of competence given that others may relate lower literacy to incompetence. Third, participants shared how text simplification technologies may not only be for DHH readers, but described shared experiences with other user groups, such as people whose first language is not English. And finally, we found that framing these technologies as something more mainstream than an assistive technology, as well as making the user-interface of these technologies more discreet or easily hidden, may help mitigate some of the issues identified.

6.1 Values and Expectations

When we asked about how they want to be seen in the workplace, most participants commented on wanting to be seen as “competent” (P1), knowledgeable (P5: “someone who knows how to get the job done”), or skilled (P4: “I think everybody wants to be seen as a skilled reliable worker”). Participants also want to be seen as reliable and responsible (P5: “I want them to think that I am a reliable person”), or someone who can be trusted to get the job done (P7: “someone who is dedicated and trusted with a job duty. To see it to completion”).

When we talked about what a good working environment would include, most participants talked about clear communication and a good sense of community in which people are accommodating to their needs, but where the support is mutual. For instance, P4 listed communication as having the topmost importance in the workplace. P1, in turn, described a good working environment as one in which “people are caring for each other and having a sense of community” and “where respect is both ways.”

6.2 Reading Skill and Intelligence

While at first none of the participants indicated they would feel offended by the recommendation of using ATS tools or embarrassed if seen by others themselves, when we asked them why they thought a third person could potentially feel those ways, most of their responses related to how literacy skill may imply a cognitive or intellectual disability, or be interpreted as the user being less capable, which could result on people looking down on them. Thus, if someone recommends an ATS-based reading assistance tool, they may be interpreted as implying that they believe the person is less capable, or as P1 puts it “If someone recommended to a person and that person may feel they are not being viewed as smart because they are implying that they have a low IQ.” If a colleague sees someone using ATS-based reading assistance tools, in turn, the colleague may interpret that as a lack of intelligence too and look down on them. P2 puts it as “it’s almost like an indication that I can’t read the original wording and that I need a text simplifier. Maybe they would look down on me that I’m not able to read,” while P6 said, “They might be like this guy’s not that smart.”

These perceptions are important because they may come in conflict with participants’ desires to be seen as competent, knowledgeable, and skilled. This may be especially amplified in a computing workplace, where open offices are now more common, as P3 puts it “I think having a level of privacy is important, like open workspaces are a trend but it is important to respect the work space.” P2 also talked about how using it in a workplace “seems public,” because “if I have my monitor up here and then I am reading something on the screen, people around me can see. So it’s the public aspect of it.”

The feelings described may also be further amplified by cultural expectations on reading and intelligence, as P4 describes “Intelligence and reading comprehension and everything is a big thing in our culture.” However, while participants expected others to think this way, they also were clear that literacy skills and intelligence are not related. For example, when talking about why someone may feel offended by the recommendation to use an ATS-based reading assistance tool, P5 said “because it would make them feel like their intelligence is being questioned [...] but it’s nothing to do with how smart they are, it is just focusing on the English literacy.” In addition to clarifications indicating that reading skill is not necessarily related to intelligence, P5 also argued that the reasons why a DHH person may struggle with reading certain texts or why ATS tools could be needed are not because of being DHH nor a lack of intelligence, but because of societal or structural issues instead. More specifically, P5 explained how “*the issue starts with the education system,*” arguing that:

The problem is because there are some deaf and hard-of-hearing people who can read and write very well, while others may not because some deaf hard-of-hearing teachers prioritize lip reading, producing speech and not focusing on English writing and reading itself. Some people may not teach them proper English reading and writing, and just focus on learning how to speak.—P5

The relationship between reading skill and intelligence was also present when participants talked about their thoughts of labeling the tool as a “simplification” tool, with three participants comparing it to “dumbing down.” While P2 thought that “simplification is a better word than dumbing down obviously,” P5 felt that they sounded alike, and P1 worried that it could have that connotation “when it is not really happening.” P3 also commented on how the technology may feel like “not giving information but also spoon feeding and that could be offensive.”

We also observed in our data that participants’ level of comfort with others seeing them using ATS-based reading assistance tools may be affected by who the onlooker is. For instance, some participants expected family and friends to be less judgemental, like P5 who said “I would feel they would be less judgmental about it than people I work with.” However, in the workplace, it may be more of an issue if the person who sees you using it is your boss or a supervisee. For instance, P2 said “I would have to justify to my boss why I’m using this tool.” P6, on the other hand, would expect feeling embarrassed if seen by a supervisee “because I am the boss.”

Finally, it is also important to note that many participants commented on how either they actually did not, or other people should not, care about what others think when using these kinds of technologies—especially when those technologies provide utility to the user. For example, using hearing aids as an example for a device people may be embarrassed to use, P4 commented “I give very little craps about what people think [...] if I could use hearing aids I would probably wear them [...] I still wouldn’t care what anybody says or thinks.” P7, in turn, focused more on how other people may be busy and how “nobody really cares what the other is doing.” But some of these same participants also suggested it was not always this way. For example, as the reason for why P3 does not worry about what co-workers think, P3 mentioned “I have been through a lot.” Similarly, P4 expects younger people to be more self-conscious, which suggests it may have taken time to get to the level of comfort where one does not care about what others think. However, even when someone may be comfortable enough not to care about what others think, there may be negative feelings involved depending on particular connotations about the technologies being used and, as mentioned above, who is watching. For instance, P4, who commented on a level of comfort being seen using assistive technologies, still had some reservations about using them in the context being seen by a supervisee if the tool has a negative connotation: “If someone that I’m in charge of sees me using a particular tool that might have a negative perception or connotation or something with it, that would really bother me.”

6.3 Not Just for DHH Readers

While many participants thought these tools would be useful, many also talked about how these tools may not just be useful for DHH readers, but other user groups may benefit from using them as well. P4, for example, was even “perplexed” by our study’s focus on DHH readers. However, most of the other participants’ comments seemed to relate to people who use English as a second language. For example, P5 talked about how “my mom whose first language is Chinese and second language is English would really benefit from this tool because she could improve and work on her English skill.” P5 also talked about how this may be beneficial for international students: “a lot of international students in graduate schools have to read a lot and it can be very tiring.”

While not all of our participants were sign language users, participants seemed to describe a shared experience between those for whom English is their second language and ASL users, like P5, who said “Some deaf hard-of-hearing people or people of color or immigrants their parents may not know English either and so they may know another language or maybe they just only know how to communicate in ASL so they don’t have the opportunity to practice English so that could impact their reading.” P5’s acknowledgment of how many DHH people may use ASL as their primary language and English only as a second language may help explain why participants’ talked about these shared experiences. However, P2 also felt that these tools could even benefit hearing people and children, and P5 also included people with intellectual disabilities.

P4, in turn, believes that complicated text is actually the author’s fault. Thus, P4 believed that using ATS tools for DHH readers was a “misguided approach,” but instead these should be tools for authors to make their writing more accessible. In P4’s words:

Similarly to Grammarly [the online writing assistant] or spell-check, this could be a tool for the author or editor of an article to make their documents more accessible from the start, rather than requiring the end user to use a tool.

6.4 Mitigating Social Accessibility Issues

In addition to participants’ suggestions that these technologies may not just be useful for DHH readers, some participants also used this same idea as a way to mitigate potentially negative perceptions of using these tools: framing or marketing these technologies in a way that does not feel like an assistive technology, but rather as something that is useful for the general population. For instance, P4 said it is “just something that anybody can use so if you ever make a tool like this it definitely needs to be marketed as for anyone.” Participants’ recommendations for alternative ways of naming these tools also seemed to reflect this, with P5 indicating that this is more of a “plain language” tool. Others, instead of focusing on complexity, thought of the tool more as a translator (P1), to a more “layperson’s English,” as a way to “un-jargon” text (P3), or to “paraphrase” (P5 and P7) or “summarize” (P5) text. Others focused on the efficiency aspect of the tool, including P6, who suggested naming it an “efficient studying tool” because “it sounds more productive and intelligent this way;” P3, who suggested calling it “ez-pz;” or P7, who suggested calling it “easy read” or “quick grasp.”

As a way to help mitigate the potential issues with using ATS-based reading assistance tools in a public space, many participants suggested designing the tools in a way that blends in with other existing tools. For example, P1 suggested that “making it look like the native text would make it less embarrassing” or if the software gives an option to “simplify the entire webpage when it is loaded so the user won’t have to manually click to simplify in front of others.” P3 recommended making it available “seamlessly like I was not using the tool, maybe [changing] the highlighter color that you use,” but making it configurable on demand. Other participants, like P3 and P6 recommended providing ways to switch back to the original text or quickly hiding the tool. For instance, P6 said “if the person really feels embarrassed, there should be a way to hide the tool fast (like a shortcut on a keyboard)” and P4 also commented, “a keyboard shortcut should be fine.”

7 DISCUSSION

In this section, we discuss the results from both of our studies, as described in Sections 4 and 6.

7.1 Reading Experiences

The results from our first study suggest that DHH individuals with work experience in the computing field read often, mostly on a screen. While participants also reported reading for personal purposes, our results suggest that a lot of their reading relates to computing-related topics, as they

are reading for work or academic purposes. By means of comparison with another activity our participants engage in (watching videos to learn about computing topics), our results suggest that they do read a lot to learn about computing topics. While videos may be preferred for learning about completely unfamiliar topics at a high-level, our results suggest that participants still read more often than watching videos when investigating topics with which they already have some deeper familiarity. Considering that NLP researchers have suggested there may be benefits from training systems based on judgements from specific user-group on specific domain [42], these findings thereby motivate further research into ATS-based reading assistance tools for DHH computing professionals as a potential user group.

7.2 Complicated Text

The results obtained from our first study also indicate that while participants do not report facing complicated text very often, when they do face it, it affects their enjoyment of reading. Participants quantified complicated text in terms of the time it takes to overcome it, and difficulty with complex or unfamiliar words was a key source of difficulty that participants reported. Thus, it is not a surprise that the most frequent workaround to facing complicated text was “looking up” words, which closely parallels the solutions that lexical approaches to ATS would provide. Further, the second most reported workaround was looking for an alternative text, which in turn parallels the solutions syntactic approaches to ATS would provide. Notably, however, our results suggest that while there may be some openness to asking others for help or clarification, our participants prefer to attempt to overcome it on their own before asking others, and thus ATS tools may be helpful to avoid asking others. Furthermore, while our participants expressed interest in the ATS tool, our results highlight that there were no commercially-available ATS tools in use by this user group as has been suggested by [62] for the general population.

7.3 Interest in ATS

We also found that there is a lot of interest overall in having a tool to assist with complicated text by making it easier to read. We note that it may be worth further exploring the relationship between this interest and users’ spoken-vs-sign communication preferences or what they consider as their first language. The main benefits participants envisioned from a tool like this were related to saving time and not having to ask others for help. Interest varied depending on the reading purpose, with participants indicating interest for such tools when reading for work, academic, medical, or legal purposes. Notably, our results on the frequency of reading for each of these purposes (Section 5.1.3), work and academic had been frequent purposes for reading, with medical and legal as more rare purposes for reading, suggesting that indeed ATS tools applied to texts in the computing domain could be explored by NLP researchers for this particular user group. Finally, it is important to note participants’ emphasis on how ATS may be beneficial to other user groups beyond DHH users, as highlighted in Sections 4.4 and 6.3. What is notable about this result is the specific group most participants in our second study emphasized, namely, non-native speakers or second-language learners; this sheds light on how DHH users view the reason why these technologies may be beneficial to them as relating to a diversity in English literacy skill as opposed to someone who is DHH.

7.4 Social Accessibility

When considering issues of social accessibility, our study revealed how the prevalent view among many people of a relationship between reading skill and intelligence was at the heart of the potential social acceptability issues with this technology. While this perceived relationship may not be a unique concern to DHH readers, potential issues arising from its perception had not been

previously identified in the context of ATS-based reading assistance tools. Our results suggest that while our participants may be comfortable being seen as DHH, and even if it takes time for many individuals to reach that level of comfort, few were okay with being seen as incompetent or as lacking intelligence. Misperceptions regarding the abilities of users of assistive technologies echo the findings of prior work social accessibility work [64], which identified potential misperceptions of incompetence that can arise if a user appears unable to use an assistive technology. Thus, those misperceptions of incompetence relate to *breakdowns* in the use of assistive technologies. In contrast, our results suggest that, in the context of ATS-based reading assistance tools, DHH users believed they could be seen as incompetent simply by using ATS-based reading assistance technologies because of the perceived relationship between reading skill and intelligence.

While prior work had identified potential ways of mitigating social accessibility issues in assistive devices or products by making them resemble more “mainstream” devices (e.g., [64]) or framing them as something other than “assistive technologies” (e.g., [53]), our work sheds light on potential solutions for social accessibility issues in the context of software tools that may be used in a workplace environment. Participants’ suggestions for characterizing these tools as “productivity tools” parallel suggestions for designing devices that resemble “mainstream” devices. However, the focus on productivity, in this case, provides more insight into the reasons DHH users identify as motivating the use of ATS-based reading assistance tools. More specifically, it seems that this motivation stems from a desire to read efficiently rather than simply identifying as DHH. Furthermore, our results also suggest that it may indeed be important to design ATS-based reading assistance tools in ways that blend in with other existing software tools, that allow them to be hidden quickly, or to be loaded for longer chunks of text at once.

These possibilities for potential design solutions need to be considered in the context of prior work in ATS which had involved designs that provide simplifications for limited amounts of text at a time in ways that are also visible (e.g., [14, 54]) which, according to our results, may present socially accessible issues. However, prior work has also identified that users may prefer systems that provide autonomy which involved visual indications of which texts have been replaced [7]. Thus, there may be tensions between the desire for visual indications to provide autonomy and the ability to have these tools blend in or be hidden easily for social accessibility, which should be further explored.

7.5 Design Considerations

Our findings also highlight aspects of the design of these technologies that may be worth further exploring:

- (1) How much text is transformed upon a single user’s request (i.e., only one word, one sentence, one paragraph, the full text) emerged as a concern, which extends the findings of prior work [7], where DHH adults indicated preferring systems that provided autonomy. The less text that is replaced per request, the more effort it requires from participants. This is independent, however, from whether the simplifications themselves happen at the lexical or syntactic level (i.e., whether only words are replaced, or sentences are rewritten too), which the present study did not explore. Both of these approaches have been found to be beneficial for DHH adults [7, 38]. Thus, future work should explore this relationship between what is replaced and how much is replaced at once.
- (2) Considering participants’ suggestions for mitigating social accessibility issues, and how these may conflict with participants’ preference for autonomy, further research is needed into the relationship between user autonomy and visual indications for replacements, while at the same time making these technologies blend in with other existing tools.

- (3) The results from our second set of interviews also shed light on other important considerations for the design of these technologies. For instance, participants' suggestions for how to name ATS tools and the way they envisioned them as not being something that should be targeted as an assistance technology for DHH readers, but potentially more as productivity tools for the general population, suggests that perhaps researchers in this area should focus on how to make universally designed tools that may benefit all. However, this does not mean that all research in the area should be done universally, as prior work has found that the linguistic sources of complexity may vary for different user groups [50]. Instead, this suggests that research focusing on the individuality of particular groups should be done within the context of striving towards universal design, identifying the shared experiences the different user groups may have as well.
- (4) Lastly, our results indicate that the relationship between the accuracy of the tool—specifically the meaning preservation of the transformations—and its usability should be further investigated.

8 LIMITATIONS AND FUTURE WORK

There were several limitations of our study: Because we conducted an online survey, we had to rely on time estimates from participants as a way to learn about their reading habits, which prior research has shown provides only a glimpse into people's reading habits—since reading is a complex social phenomenon that looks differently in different contexts [37]. While we tried to mitigate this by comparing reading specifically in the workplace against another activity (i.e., watching video), it is difficult to obtain accurate estimates of every reading activity our participants may engage in.

A second limitation was the sample size of our study: Because we were looking at a specific user group, i.e., DHH adults with work experience in the computing field, our sample size was not large enough to support fully investigating whether there may be a relationship between users' interest in reading assistance, and with various demographic factors, e.g., participants' communications preference. In future work, research with a larger population of DHH in the United States could look deeper into this issue by building regression models with the demographic factors. Similarly, research with the larger DHH population in the United States could examine how their interests and needs may differ from those in the computing industry. Considering participants' comments regarding age and personal acceptance of assistive technology use, larger sample sizes could also enable the investigation of a potential relationship between age and concerns about social accessibility issues.

Our study design was based on survey and interviews, which included a brief video demonstration of reading assistance tools. We had asked participants to imagine using the such tools, to gain insights into their views on various design issues. While our video had shown both lexical and syntactic approaches to text-simplification, we did not compare these approaches in this study, as we were concerned that our short video may not provide sufficient context to differentiate these approaches. Future work can also include usability studies that focus on the comparison of both of these approaches. Furthermore, the color coding used in the video demonstration for complex and simplified text (gray and yellow, respectively) was based on suggestions from DHH participants during pilot studies with a prototype; however, future work should also ensure that the color coding used for prototypes deployed in the wild is accessible for users with color blindness.

While our work has examined this specific user group, in a specific domain, future studies could investigate the needs and interests of other user groups and in other domains, who may also benefit from ATS-based reading assistance tools. Further, because we were focusing on DHH computing professionals, our participants' self-reported English levels and level of education may not be fully representative of the entire DHH population in the United States or other parts of the world. Thus,

future work may focus on the interests of DHH adults with lower levels of literacy or education, to understand how their views may differ. Finally, considering participants' comments on English as a second language, future research could also focus on comparing the perceptions on ATS-based reading assistance tools of Deaf signers and DHH people who primarily use English or other spoken languages.

Finally, there are critical design considerations that emerge from our results regarding issues of social accessibility, autonomy, and accuracy, as well as potential directions for mitigating issues that may emerge in those respects. Thus, future work should be using different methods should explore how our findings may translate to the actual design of technologies, including how to manage the relationship between user autonomy and privacy in using these tools when needed, how to balance moving towards universal design while also attending to potentially different user needs, and how to provide users with more confidence about how well the systems are performing.

9 CONCLUSION

Through a survey and follow-up interviews with a subset of survey respondents, our study investigated the needs and interests of DHH individuals in the computing field for ATS-based reading assistance tools. Our results suggest that DHH individuals read often, frequently on electronic devices and to learn about new topics for their work, and indicated strong interest in ATS-based reading assistance tools. Our results also include a prioritized list of the most frequent workarounds our participants currently use for overcoming complicated text, with looking up words and finding other texts with the same content, which are analogous to typical ATS approaches, being the most frequent ones reported by participants. We also provide a prioritized list of reading purposes for which participants reported interest in using ATS-based reading assistance tools, as well as their frequent purposes for reading. These findings thereby motivate further technical work on such tools for this user group, which may require gathering user-and-domain-specific datasets for this setting, as needed by NLP researchers. Finally, our results provide insights into certain design considerations for ATS-based reading tools, namely expanding the user autonomy they provide, and highlighting participants' concerns about ATS accuracy and the social accessibility of these technologies. These findings, in turn, motivate further design work into such tools for this particular user group.

APPENDIX

A ONLINE APPENDIX

This appendix describes the content of the online appendix we have provided as electronic supplementary material.

- **Survey Questionnaire.** This is a PDF file that contains the questionnaire used in the online survey described in Section 3.2.
- **Survey Follow-Up Interview Questionnaire.** This is a PDF file that contains the questionnaire used in the interviews conducted with a subset of the survey respondents as a follow-up, described in Section 3.3.
- **Social Accessibility Interview Protocol.** This PDF file contains the questionnaire and protocol for the interviews focused on the social accessibility of ATS tools, as described in Section 5.
- **Video Demonstration.** This is an MP4 file that contains the video demonstration displayed to participants through the studies presented in this article. A version of this video with audio descriptions is also included.

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Received May 2021; revised January 2022; accepted February 2022