Reading Experiences and Interest in Reading-Assistance Tools Among Deaf and Hard-of-Hearing Computing Professionals

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ABSTRACT

Automatic Text Simplification (ATS) software replaces text with simpler alternatives. While some prior research has explored its use as a reading assistance technology, including some empirical findings suggesting benefits for deploying this technology among particular groups of users, relatively little work has investigated the interest and requirements of specific groups of users of this technology. In this study, we investigated the interests of Deaf and Hard-of-Hearing (DHH) individuals in the computing industry in ATS-based reading assistance tools, motivated by prior work establishing that computing professionals often need to read about new technologies in order to stay current in their profession. Through a survey and follow-up interviews, we investigate these DHH individuals' reading practices, current techniques for overcoming complicated text, and their interest in reading assistance tools for their work. Our results suggest that these users read relatively often, especially in support of their work, and they were interested in tools to assist them with complicated texts. This empirical contribution provides motivation for further research into ATS-based reading assistance tools for these users, prioritizing which reading activities users are most interested in seeing application of this technology, as well as some insights into design considerations for such tools.

CCS CONCEPTS

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

KEYWORDS

Automatic Text Simplification, Reading Assistance, People who are Deaf or Hard of Hearing,

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1 INTRODUCTION

Automatic text simplification (ATS) consists of a variety of computing techniques for rewriting or modifying a text to improve its readability and understandability, and these transformations typically occur at the lexical level (replacing individual words), at the syntactic level (modifying the structure of sentences), or a hybrid of both [42]. Recent work has investigated how ATS can be used as an assistive technology to provide reading assistance for a variety of user groups, including people with aphasia or dyslexia [11, 34], low-literacy adult readers [49], as well as language learners [4]. Most work in this area has focused on evaluating the underlying technology itself, i.e. the quality of the text that had been processed by ATS systems (e.g. [37]), identifying linguistic properties that affect text readability for different user groups [31, 35], measuring the benefits of providing ATS-based reading assistance tools [2, 23, 27], and, in a few cases, investigating design aspects of the user-interface of such tools [2, 36]. However, little work has considered the needs and interest in using such tools among a specific target user group; one prior study investigated the needs and interests in assistance tools for reading online reviews among adults with autism [52]. No prior work has investigated reading-assistance needs and interest among people who are Deaf or Hard of Hearing (DHH). No prior work had examined a computing professional context, nor whether users' interest may vary depending upon their specific reading task.

Some prior natural language processing (NLP) research on ATS technologies has made use of datasets of judgements from end users on the complexity of words [25], with researchers suggesting it may be useful to gather additional datasets for specific groups of users or vocabulary in specific domains [25]. Motivated by this trend, in this study, we explore the needs of DHH individuals working in a specific field, computing and information technology, in regard to ATS-based reading assistance tools.

Fifteen percent of U.S. adults are DHH [7], and prior research has found that there is great diversity in the literacy skills of these individuals. While some are strong readers, studies have also reported median reading skill of DHH high school (secondary school) graduates in the U.S. being at the "fourth-grade level," which is a standard for U.S. students in elementary school typically at age 9 [47]. Other studies have found that over 17% of deaf adults can be considered as readers with low literacy [14]. Furthermore, research has found lower educational outcomes among DHH adults when compared to hearing peers [15], as well as lower rates of employment and lower salaries [48].

In addition to the reading skills necessary in personal and social contexts, written language literacy is also important for professional success for many fields. For instance, lower reading skills may pose challenges to individuals working in the computing and information technology field, as prior research has established that such workers are often required to learn about new topics on their own to keep their technical skills up to date [41]. Prior work has found that computing professionals rely to a large extent on reading text-based resources for this learning and thus low literacy may pose a challenge for computing professionals who are DHH [53]. Furthermore, people who are DHH are underrepresented in the computing field, with a recent Stack Overflow survey finding that only 0.8% of users identified as DHH [46]. This underrepresentation thereby motivates research on potential barriers to professional success.

Thus, in this work, we conducted a survey of 32 people who are DHH with experience working in computing and information technology fields, to investigate their needs and interests in ATS-based reading-assistance tools. The questionnaire included a brief non-interactive video demonstration of ATS-based reading assistance tools so that participants could discuss their interest in using such technologies. After the survey study, follow-up interviews were conducted with five respondents to gain a deeper understanding into the survey results.

We found that the majority of participants reported reading several times a week, with most reading occurring on an electronic screen, for work or academic purposes. Participants reported that their most frequent workarounds when encountering complex text was to look up words in a dictionary or searching for other websites with an easier-to-read version of the same content. Most participants "strongly agreed" with being interested in ATS-based reading assistance tools; in fact, participants were especially interested in such tools when reading for work, academic, medical, or legal purposes. Most participants indicated they would be upset if the tool replaced text before they had a chance to see the original version, or if it replaced text without asking. Some participants expressed concerns about being embarrassed if a colleague noticed them using a reading assistance tool, and they also were concerned about the accuracy of the system, namely, whether it might misinterpret the meaning of the text it replaces.

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 there was 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 results also provide insight into certain design considerations for ATS-based reading assistance tools: expanding prior research on DHH users' preference for such technologies providing autonomy [2], highlighting DHH users' concerns about ATS accuracy, and motivating further research into the social acceptability of these technologies.

2 BACKGROUND AND RELATED WORK

In this section, to establish the context for our work, we describe prior work on the use of ATS as a reading assistance tool, both for DHH readers and other user groups. Then, we describe research looking into DHH adults in the workplace and their general reading habits.

2.1 Automatic Text Simplification and Reading Assistance

As discussed above, prior standardized testing has measured a median of fourth-grade reading levels among DHH high school graduates in the United States [47], with other studies on reading comprehension reporting sixth-grade reading levels among DHH university students [1, 32]. Furthermore, prior research has described over 30% of deaf high school graduates in the United States as "functionally illiterate" [28], with other studies suggesting that over 17% of deaf adults have "low literacy" [14]. Notably, these findings are not reflective of all DHH adults, as there are also many DHH adults who are excellent readers. Thus, what this prior research suggests is that there is great diversity in literacy skills among DHH readers and that there is a significant subset of these adults who face difficulty reading.

Prior research has also examined the particular literacy profile of DHH readers, which sheds light on aspects of the reading task that may be the greatest challenge. For instance, some prior work on DHH readers has identified syntactic structure as a potential source of reading difficulty [10]. However, recent research has also suggested that syntax is not the only source of difficulty, as vocabulary knowledge also plays a role in the diversity of DHH readers' literacy [9, 24]. Furthermore, research into the reading strategies employed by DHH readers has also identified unfamiliar vocabulary as a key challenge [5]. Due to the literacy challenges that many DHH readers face, ATS tools provide a possible solution. Furthermore, the specific research on DHH reader's literacy summarized above motivates research into a variety of ATS technologies, operating at various linguistic levels, to support DHH readers.

ATS consists of computing techniques to rewrite text to improve its readability or understandability, and thus it involves the identification of complex text, as well as the generation and selection of appropriate alternatives. The main approaches to ATS can be classified as: syntactic simplification, which modifies the

structure of phrases or sentences to reduce their grammatical complexity; lexical simplification, which replaces complex words with simpler synonyms [42]; or hybrid combinations of both in which both the syntactic structure is modified and complex words are replaced.

Prior work on the use of ATS as reading assistance tools for people who are DHH has involved measuring whether users benefit from the various approaches, e.g. with one study identifying comprehension benefits from syntactic approaches [23], and another measuring how users perceived a benefit from lexical approaches [2]. The latter study identified that DHH users' acceptance of ATS tools are modulated by the degree of autonomy that the system provides to users, i.e. controlling for which words simplification is requested and visually indicating which words in a text had already been replaced by the technology.

In addition to this prior ATS research focused on DHH readers [2, 20, 23], more broadly, there has also been related work on ATS-based reading-assistance tools for other user groups, including people with aphasia [11], people with dyslexia [34], non-native speakers [4], or other low-literacy readers [49]. There have been many user studies in this area, focusing on different aspects of the systems. For instance, some research has looked at the evaluation of the quality of the text produced by ATS systems, traditionally measured by "expert" readers – usually native speakers – rather than the target users (e.g. [17, 37, 51]).

Prior ATS studies that have focused on specific target user groups have investigated whether users benefit from the different approaches to text simplification [2, 23, 27], or comparing how the use of different systems impact those benefits [35]. Other work has focused on identifying the linguistic needs of different user groups (i.e. which linguistic properties affect the readability of a text), finding that the linguistic properties that affect readability for different user groups may not always be the same [31, 35]. Finally, some research has focused on investigating design aspects of the user-interface of tools providing ATS as a form of reading assistance for adults who are DHH (not necessarily in computing) [2]. However, our work focuses on understanding the general needs and preliminary interest in ATS tools among a specific target user group. While one prior study investigated the user needs and interest of adults with autism for reading in ATS tools for reading online reviews [52], no prior work has focused on DHH users, nor the more specific context of computing professionals.

2.2 Need for Domain-Specific User Research

ATS research has recently emerged as a sub-field of natural language processing research (NLP), and a challenge has been access to training data (e.g. simplification corpora) [42]. As mentioned in the Introduction, one approach that has been used to address this challenge is the collection of datasets of judgements from non-native English speakers on the complexity of words, in order to train their simplification models [25]. Maddela and Xu [25] propose that it would be useful to gather additional datasets for specific user groups or vocabulary on specific domains (e.g. medical, computing, legal, etc.). Thus, in order to construct such datasets for these particular user groups, within particular domains, it is necessary to conduct fundamental user research into user's reading habits, reasons for reading, and other details of a particular group of readers in some domain.

Since we wish to understand the needs and interests of DHH users working in the computing field, towards the design of a potential assistive technology in a workplace environment, we also examined prior research into various assistive technologies for DHH users in the workplace. Most prior in this area, however, has centered around the use of Automatic Speech Recognition (ASR) and captioning. Prior research includes investigations of ASR as a way to facilitate communication with hearing colleagues [12] or customers [26], and even how hearing people may behave differently when using these technologies, which might affect the technology's performance [40]. However, to the best of our knowledge, no prior work has investigated the reading behaviors of DHH individuals in the workplace, nor their interests for assistive technologies to assist with those reading tasks.

2.3 DHH Readers' Reading Habits

In order to understand the needs and requirements for reading-assistance tools among DHH users in the computing and information technology field, it is useful to characterize their reading habits in terms of how much reading they do now and what purposes they read for, as well as what tools or workarounds they currently use to overcome complicated text. When considering related work for the latter, prior literacy research has investigated the reading strategies DHH readers used to understand text (e.g. [5, 8, 18, 39]). This prior research has primarily focused on the inferential and metacognitive strategies – i.e. strategies that rely on the reader's own awareness and control of their understanding – employed by readers internally, such as constructing alternative meanings for individual words, substituting familiar words unfamiliar text with familiar paraphrases, or translating words into American Sign Language (ASL) [5]. However, to the best of our knowledge, no prior work has investigated specific external tools users employ to assist them in overcoming complicated text.

While some prior work above has examined how DHH individuals engage in reading, relatively little work has investigated DHH reader's reading habits. The only such study we have found, conducted with both DHH and hearing university students as participants, found that DHH participants reported reading more often (ranging from 6 to 56 hours a week) than hearing students (ranging from 1 to 43 hours a week) [29]. Furthermore, the results of that study found that DHH participants' most frequent reading activities involved e-mail and other Internet media [29].

Prior research investigating the reading habits of the overall American population (not specifically among DHH individuals) has varied widely in how they measure and report their results. For instance, some studies have reported general frequency of reading, with 80% of survey respondents in one such study reporting they read occasionally for pleasure and 50% of full-time workers reporting they read every day for work or schooling [33]. Others have reported amount of time reading on a day, with one such study finding that individuals ages 15 to 54 read on average 10 minutes per day [3], and another one estimating that the overall population reads on average 15.6 minutes per day [50]. They have also varied in what they investigate. Some prior work, for instance, investigated

how often people read for work or academic purposes as compared to leisure (e.g. [19, 22]), for leisure alone (e.g. [3, 16]), or books (e.g. [54]), with the latter finding that 62% of respondents read a book at least once a week. Others, in turn, have focused on how different demographic factors may affect their reading habits, such as race (e.g. [38]), reading proficiency (e.g. [43]) or levels of education and occupation (e.g. [22, 45]).

However, these findings – for DHH readers or Americans in general – may not generalize to DHH workers, let alone in a specific field: Prior research by Kirsch and Guthrie (not specifically on DHH readers), found that the "setting" (i.e. work vs. leisure) and an individual's occupation both affected their reading practices [22]. Thus, they suggest, when investigating the reading practices of a particular user group, it requires investigating the contexts and settings of interest in which reading occurs, as well as characteristics about the readers and their reading practices. 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 examine their reading habits and contexts of interest to them, and which of these contexts users would be interested in having ATS-based reading assistance.

3 RESEARCH QUESTIONS

Thus, with this context, 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 paper-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 industry interested in ATS-based reading assistance tools? And if so, for which reading activities would they be interested in it for?

4 METHOD

To investigate domain-based user needs for reading assistance tools based on automatic text simplification, 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 information technology 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.

4.1 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 8 participants who identified as culturally Deaf[1] <fn id="fn1"> Here and elsewhere in the paper, we follow the convention of capitalizing the word Deaf to refer to members of Deaf culture, as explained in [30]. </fn> [30], 3 as Hard-of-hearing and 1 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.

4.2 Survey

4.2.1 Participants. Our participant-selection criteria included identifying as Deaf or Hard-of-Hearing, as well as having had work experience (including internships) in the computing or information technology within the past 5 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 by participants included high school (N = 4), associates (N = 9), bachelor's (N = 13) and masters (N = 6), with 17 out of 32 participants indicating they are still students. Participants had an average of 5.5 years of work experience (SD = 7.37), ranging from less than a year to 32 years. There were 8 participants who identified as deaf, 12 as culturally Deaf [30], 10 as hard-of-hearing, and 2 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 6 participants who preferred spoken language only; 7 who indicated mostly spoken language, with a little sign language; 6 who preferred about half of each; 6 who preferred mostly sign language, with a little spoken language; and 6 who preferred only sign language. Lastly, most participants reported

[1]Here and elsewhere in the paper, we follow the convention of capitalizing the word Deaf to refer to members of Deaf culture, as explained in [30].

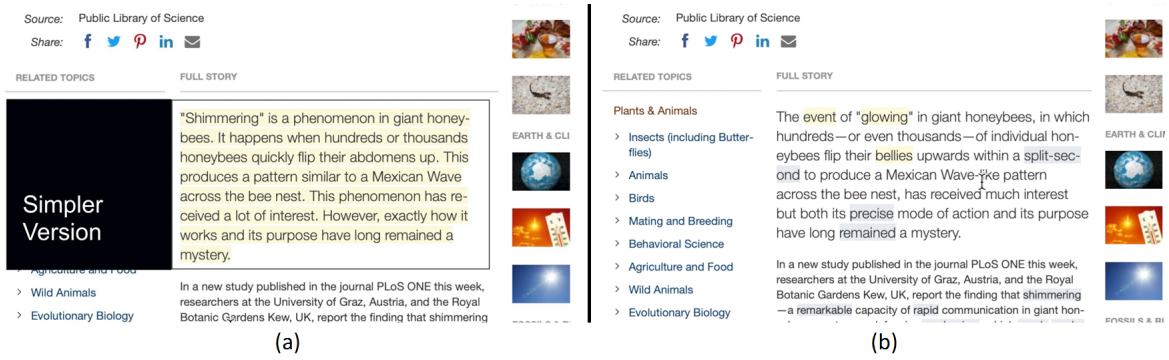

Figure 1: Screenshots from the video demonstration shown to participants in the survey and follow-up interviews demonstrating (a) syntactic simplification and (b) lexical simplification. Simplified text is highlighted in yellow, while in (b), words identified as complex are highlighted in gray.

feeling very comfortable with reading English (N =18), while others indicated feeling comfortable (N = 8), neutral (N = 5), and not comfortable (N = 1).

4.2.2 Materials. The survey, hosted using Qualtrics, consisted of 30 questions, and it required approximately 15 minutes to complete. 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, which showed a demo 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 [2]. Figure 1 shows screenshots of this video demonstration, and the original video is shared as an electronic appendix with this paper – along with a complete copy of our survey questionnaire.

4.2.3 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 was 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 user's communication preference and their interest in the ATS tool in different contexts, Spearman correlation analysis was performed for this non-parametric data.

4.3 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 study. Afterward, we will provide a combined results section of both the survey and the interview results, in an interleaved manner.

4.3.1 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 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.

4.3.2 Procedure. A total of 7 participants who had responded "yes" to whether they would be willing to participate in interviews were randomly selected and contacted via e-mail, and 5 of these individuals responded to this request for an interview appointment. These 5 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 were compensated with $40 for their participation.

4.3.3 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 associates (N = 1), bachelor's (N = 3) and masters (N = 1), with 3 participants indicating they were still students. Participants had 3.8 years of experience on average (SD = 1.48), ranging from 2 to 6. There were three participants who identified as deaf, while the other two identified as 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.

4.3.4 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.

5 RESULTS

In this section, we present the results of 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.

5.1 Reading

5.1.1 Reading Frequency. Following the methodology of [22], we asked participants in the survey to report their frequency of reading 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 7 who reported reading two to three times a week. Another 3 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 U.S. population in prior work (as discussed in Section 2.3), our participants' frequency of reading was relatively similar.

5.1.2 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, etc.) 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 7 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 ($p < 0.01$).

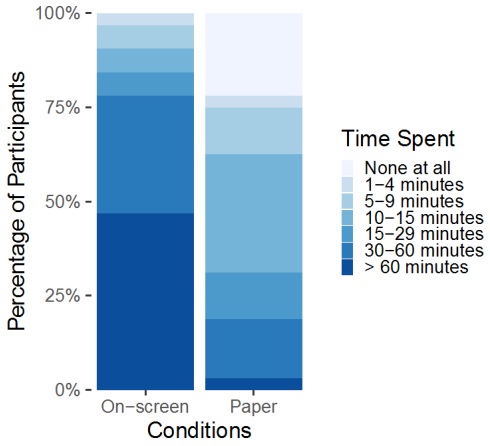

Figure 2: Participants' responses to the questions: On a day that you read, how much time do you spend reading text (a) on a screen (e.g. computers, laptops, phones, tablets, etc.) and (b) that is not on a screen (e.g. books, magazines, newspapers, print-outs). There was a significant difference between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

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.

5.1.3 Purposes for Reading. We then asked participants in the survey about the purposes for which they read, 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 papers, 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), 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

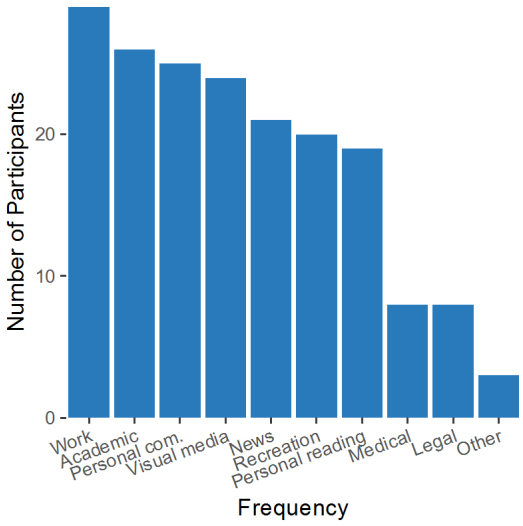

Figure 3: Counts for responses to the different reading purposes included as options for the question "For what purposes do you read? (select that apply)."

(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 8 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[2]<fn id="fn2"> No proofreading corrections were performed on P1's comments, who typed their own responses during a chat-based interview. </fn> 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, they prefer reading content such as stories "with simpler words" (P2) or "that are simple like thriller novels and not like Shakespeare" (P1).

5.2 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 [6], 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, 9 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 9 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).

5.3 Complicated text

The survey asked participants to rate "how often do you encounter 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 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

[2]No proofreading corrections were performed on P1's comments, who typed their own responses during a chat-based interview.

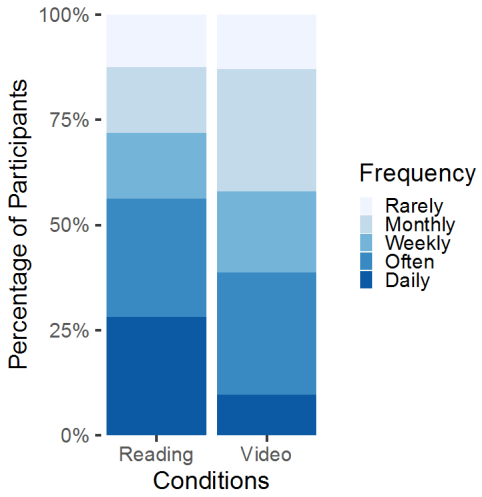

Figure 4: Participants' responses to the questions: "How often do you read to learn about technical topics for your work (e.g. information about new technologies, new software, programming information, etc.)?" and "How often do you watch videos to learn about technical topics for your work (e.g. information about new technologies, new software, programming information, etc.)?" 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 ($p < 0.05$).

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 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."

5.3.1 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 American Sign Language, 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 4.1) as well as considering whether there exist external tools analogous to internal metacognitive strategies employed by DHH readers who encounter complex text [5]. 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).

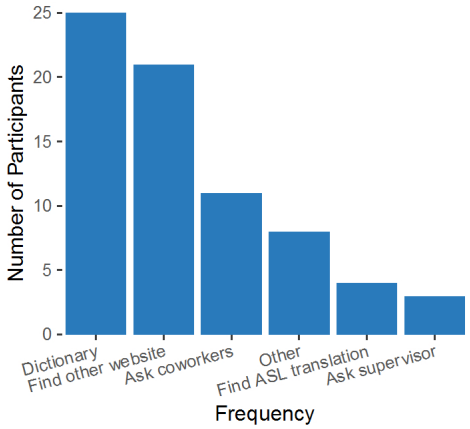

Figure 5: Counts for responses to the different reading purposes included as options for the question "How do you try to understand text that is complicated? (select all that apply)"

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."

5.4 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. 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 paper. 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 was shown to all 5 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

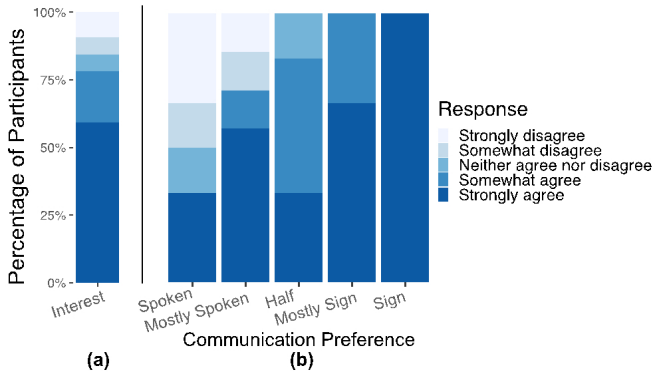

Figure 6: Participants' agreement to a Likert-scale question "I would be interested in a tool that helps me to understand text by making it simpler" (a) overall and (b) broken down by communication preferences. Communication preference levels: Spoken = "Spoken language only", Mostly Spoken = "Mostly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

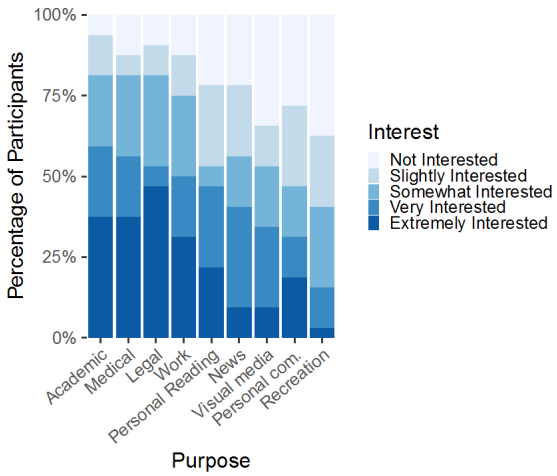

Figure 7: Participants' Likert-scale responses to the question "Please choose your interest in a tool like the one in the video for each activity below."

mentioned by participants included learning new words (P2 and P4), as well as reducing frustration (P5) and increasing confidence (P1). Notably, 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)."

5.4.1 Tool Interest and Communication Preference. Considering that prior work with DHH users in other domains (e.g. sound-awareness technologies [13] or sign language animations [21]) 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 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.

5.4.2 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.

5.5 Design considerations

5.5.1 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 [2]. 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, autonomy was not a topic that arose, except for one participant who 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.

5.5.2 Social Acceptability. Considering issues of social acceptability in assistive technology design [44], 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 judgement 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."

5.5.3 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%."

6 DISCUSSION

Our results 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 [25], these findings thereby motivate further research into ATS-based reading assistance tools for DHH computing professionals as a potential user group.

Our results 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 ATS tool, our results highlight that there were no commercially-available ATS tools in use by this user group as has been suggested by [42] for the general population.

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, in our results on 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.

Our results highlight three aspects of the design of these technologies that may be worth further exploring. First, 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 [2] 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 *simplification*s 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 [2, 23]. Thus, this relationship between *what* is replaced and *how much* is replaced at once is important to explore. Second, our results suggest it is worth further exploring how to mitigate the social acceptability of these tools, since that may vary depending on the environment users are using it in. 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.

7 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 [22]. 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 assistant, and with various demographic factors, e.g. participants' communications preference. In future work, research with a larger population of DHH in the U.S. could look deeper into this issue by building regression models with the demographic factors. Similarly, research with the larger DHH population in the U.S. could examine how their interests and needs may differ from those in the computing industry.

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. However, there are critical questions that emerge from our results regarding issues of social acceptability, autonomy and accuracy, which shall be explored in future work through usability studies with interactive prototypes. 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.

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. Finally, 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 U.S. 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.

8 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 acceptability of these technologies. These findings, in turn, motivate further design work into such tools for this particular user group.

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