Accessible Text Tools for People with Cognitive Impairments and Non-Native Readers: Challenges and Opportunities

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ABSTRACT

Many people have problems with reading, which limits their ability to participate in society. This paper explores tools that make text more accessible. For this, we interviewed experts, who proposed tools for different stakeholders and scenarios. Important stakeholders of such tools are people with cognitive impairments and non-native readers. Frequently mentioned scenarios are public administration, the medical domain, and everyday life. The tools proposed by experts support stakeholders by improving how text is compressed, expanded, reviewed, and experienced. In a survey of stakeholders, we confirm that the scenarios are relevant and that the proposed tools appear helpful to them. We provide the Accessible Text Framework to help researchers understand how the different tools can be combined and discuss how individual tools can be implemented. The investigation shows that accessible text tools are an important HCI+AI challenge that a large number of people can benefit from.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Empirical studies in interaction design**.

KEYWORDS

Accessibility; People With Cognitive Impairments; People With Intellectual Impairments; Non-Native Speakers; Easy Language; Plain Language; Machine Translation; Text Summarization

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1 INTRODUCTION

The ability to read is an important prerequisite for participation in society, both online and offline. Up to 13.7% of people worldwide are illiterate [99]. These people cannot read or write a short, simple statement in their everyday life [98]. An even larger group of people is functionally illiterate. The United Nations consider a person to be functionally illiterate if he or she "cannot engage in all those activities in which literacy is required for effective functioning of his [or her] group and community and also for enabling him [or her] to continue to use reading, writing and calculation for his [or her] own and the community's development" [98].

Illiteracy and functional illiteracy can be found in a large number of countries, even if the overall literacy of the country is high. Germany, for instance, is one of the best-performing countries in the Programme for International Student Assessment (PISA), which evaluates educational systems in different countries. The German reading score in the ranking is well above the average [75]. Nevertheless, the 2018 Living With Low Literacy study found that 12.1% of German citizens are either functionally or fully illiterate [35, 36].

The primary goal of this investigation is extending prior work [43] to provide the foundation for software tools that enable as many people as possible to engage in all those activities in which literacy is necessary. To facilitate this, we examine what kind of accessible text tools are needed to support users. We operationalize the term accessible text tool as any kind of socio-technical intervention that can make text more accessible. Following the dictionary definition of *accessible* as something that can be understood, appreciated, or used readily [77], we want to develop tools that make it easy for people to understand the information conveyed in text. To empirically study what accessible text tools should be developed, we used a mixed-methods study design. First, we conducted interviews with 18 experts from different fields. The experts imagined a number of possible solutions. We then surveyed 175 stakeholders to validate our findings. Based on our empirical insights from two studies, we address the following research questions:

- RQ1: In what scenarios would accessible text tools be especially useful?
- RQ2: Who do experts think could benefit the most from accessible text tools?
- RQ3: Which accessible text tools are useful to stakeholders?
- RQ4: What should the interface of accessible text tools look like?

To answer the first research question, we collected usage scenarios in which the tools may be particularly helpful (RQ1). The scenarios proposed by experts include finding information about an upcoming election, receiving a bill from a doctor, and understanding the COVID-19 rules and restrictions. The interviews showed that people with cognitive impairments and non-native readers are potential stakeholders for accessible text tools (RQ2). The experts also discussed how and why everybody can benefit from such support. The survey confirmed that the stakeholders perceive the accessible

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text tools as helpful (RQ3). The survey also yielded insights into what the interface of the accessible text tools should look like (RQ4). Based on these findings, we propose the Accessible Text Framework to enable designers and developers to understand the conflict of goals between the different tools and to outline a way to overcome this. The framework groups the accessible text tools based on their purpose: compressing text, expanding text, reviewing text, and experiencing text. To accelerate the development of accessible text tools, we connect the expert proposals to state-of-the-art research in the field of natural language processing. We hope such tools will enable more people to fully participate in society.

2 BACKGROUND & RELATED WORK

Our work is an extension of investigations of the user experience of translation systems [43], which showed that poor quality translations can lead to breakdowns in conversations and overall frustration of users [39, 103]. However, Hara and Iqbal found that users can adapt to a system and its limitations, e.g., by rephrasing or repeating their input or by providing additional information [39]. Nevertheless, even well-performing machine translation systems require users to assess the translation and to identify errors [51], which can be challenging for users.

2.1 Accessible Text

We use the term accessible text tools as an umbrella term for any kind of socio-technical intervention that helps people understand text. Accessible text tools connect to related work in accessibility, e.g., on how to augment face-to-face conversations for people with autism spectrum disorder [11] and on how the literacy levels of users can influence the comprehension and opinion of automatic captions of deaf or hard-of-hearing users [7, 50]. Our goals connect to a large body of research that investigated the recognition, generation, and translation of sign language [13, 14]. Our work is orthogonal to projects that support people with aphasia [27, 64]. Examples of this include HAPPI (Helping Aphasic People Process Information), which were developed to support aphasic people by simplifying language using lexical simplifications, e.g., by presenting users with more common or easier words [27]. Another example is Mahmud and Martens's aphasia-friendly email tool, which was shown to help users improve their email communication and positively influenced the number and quality of social contacts for people with aphasia [64]. Our work is also informed by research that showed that the user interface can improve text comprehension, e.g., by fading out text [53].

Our operationalization of accessible text is motivated by the large number of different terms to describe what we call accessible text and the confusion that stems from this. For the German language, Maaß distinguishes between Easy Language, Easy Language Plus, Plain Language, and Expert Language [61]. Easy Language (German "Leichte Sprache" [16, 60]) was initially designed for people with cognitive impairments. Plain Language (German "Einfache Sprache" [73]) was meant to open expert content for laypeople. Maaß distinguishes the main contrasting characteristics of Easy Language and Plain Language: Easy Language is characterized by perceptibility and comprehensibility, while Plain Language is characterized by acceptability and its propensity to avoid stigmatization [61].

This paper expands on research on what makes a text understandable. Our research is informed by the Hamburg comprehensibility model, which lists four characteristics that make it easy to understand a text: (1) linguistic simplicity (i.e., usage of common words, explanations for difficult words, and simple and short sentences), (2) arrangement structure / cognitive structure (i.e., a meaningful order of information), (3) concision (i.e., that the length of the text is in relation to the information target), and (4) motivation (i.e., the text uses examples that are relatable for the audience) [56, 67].

2.2 Accessibility Research

In this paper, we prefer the term people with cognitive impairment over the term people with disabilities. This is informed by the activists of the emergent disability rights movements of the 1960s who framed disability "as a socially and culturally constructed form of societal oppression" [29]. Their "social model" distinguishes between an individual's impairment as a biological or physical condition and disability as a social and environmental construction [32]. We adopt an affirmative approach towards such impairments. This affirmative approach is inspired by Spiel et al., who investigate the agency of children with autistic spectrum disorder (ASD) in technology research [88]. Spiel et al. advocate research geared toward the interests, needs, and desires of autistic children. With this perspective in mind, we follow an affirmative approach toward cognitive impairment and examine ways of making information environments more accessible to all people. Our approach is informed by Gibson et al., who investigated how to deeply involve adults with mild intellectual impairments in the design of interactive systems [22]. They showed how to explore users' views and involve "experts". Our work is informed by Holone and Herstad, who examined the tension in participatory design that arises when co-designing with children with severe impairments [45]. They reflect on the ideal of active participants and relate this to children's roles as recipients. They also discuss the challenges of direct communication and the use of proxies, e.g., helpers that interpret the actions and reactions of the child. They recommend approaching the ideals of participatory design with a sense of pragmatism to accomplish the goals.

In this context, it is noteworthy that people with impairments have always been among the earliest adopters of artificial intelligence. As such, they are among the people with the most experience with what it means to work with AI, to be excluded by AI, and to trust AI [8]. At the same time, we find that contemporary accessibility research strongly focuses on blind and low vision (BLV) users [62]. Despite our best efforts, we did not find HCI research on how to support functionally illiterate people through technology. We address this gap by focusing on people with cognitive impairments and non-native readers.

In this investigation, we engage with different groups of stakeholders. Our investigation findings indicate that tools for people with cognitive impairments can also be helpful for everybody. Our investigation directly relates to the ideas behind universal design. The United Nations Convention on the Rights of Persons with Disability defines the term universal design as "the design of products,

environments, programs, and services to be usable by everyone, to the greatest extent possible, without the need for adaptation or specialized design" [93]. This directly connects to the term Design for All [6]. Examples of such universal design include curb cuts, automatic door openers, and movie captions. A number of other publications have demonstrated the potential of universal design for human-computer interaction, e.g., in relation to older adults with dementia [24], with Autism Spectrum Disorder [84], and people with visual [12] or mobility impairments [58].

2.3 Accessible Text in Practice

A large body of research has focused on using technology to help different stakeholders. This paper investigates in which scenarios such tools are helpful and who would benefit the most. A 2017 investigation in Spain by Chiner et al. found that 90% of people with intellectual impairments use smartphones, compared to 69% who use a laptop and 61% who use a computer [20]. As popular Internet use cases, they identified listening to music (84%), watching videos (77%), and chatting with friends (70%). Only every third (33%) person with intellectual impairments reports reading texts online. In addition to that, only every fourth person (25%) with intellectual impairments reads a newspaper. These findings indicate that tools that make text more accessible can support many people with intellectual impairments who use technology but do not read online. The numbers are corroborated by a 2019 study from Sweden by Ågren et al. [106]. In this sample, 67% of adolescents with people with intellectual impairments have access to a smartphone, compared to 98% of adolescents without impairments. Only 20% of young people with intellectual impairments search for knowledge and information online, compared to 86% of young people without impairments. Participants were also asked about the difficulty of understanding information on the Internet. One out of five (21%) people with an intellectual impairment state that they never understand information on the Internet. Another 24% of people with intellectual impairments find it very difficult to understand information. With accessible text tools, we want to enable more people with and without cognitive impairments to search for new information and knowledge online, especially news. In a 2010 study, Feng et al. also specifically investigated computer usage of children with Down syndrome [31]. They identify cognitive limitations, e.g., language difficulties and frustration, general cognitive difficulties, physical limitations, e.g., regarding typing or mouse usage, software problems, and societal difficulties. These findings connect to Johansson, who studied participation in the digital society with a focus on people with cognitive impairments, people with mental health issues, and people without a home [49]. He identified fourteen prerequisites to participation. He also argues that to promote participation, a toolbox of methods and accessible tools is needed. Informed by this prior work, we explored accessible text tools.

2.4 Text Simplification & Text Summarization

Text simplification has been studied for a variety of languages, including frequently spoken languages like English [25, 101], Spanish [10], and German [52, 91] as well as less frequently spoken languages like Swedish [26] and Basque [34]. This paper focuses on German, the most spoken native language within the European Union and the 12th most frequently spoken language worldwide [100].

Saggion describes automatic text simplification as "the process of transforming a text into another text which, ideally conveying the same message, will be easier to read and understand by a broader audience" [80]. This process includes replacing difficult or unknown phrases and changing long and syntactically complex sentences into shorter and less complex ones. Saggion et al. [81] developed a modular system that performs syntactic and lexical simplification to simplify Spanish text. They evaluate the system using readability metrics for Spanish as well as human evaluations.

Al-Thanyyan and Azmi provide an overview of resources and corpora, evaluation metrics, and simplification approaches [2]. These approaches include lexical-, syntactical-, machine translation- and hybrid approaches. Researchers developed such automated text simplification [2, 4, 78, 83, 85]. In their seminal work on the automatic induction of rules for text simplification, Chandrasekar and Srinivas explore natural language processing (NLP) methods to automatically transform long and complicated sentences into simpler ones [19]. Considering the complexity of hand-crafted rules, they propose inducing the simplification rules from data. More recent approaches follow this approach and leverage statistical machine translation [87, 102], deep recurrent neural networks like long short-term memory networks [74], or deep reinforcement learning [105]. We will engage with these approaches in the Discussion of this paper. Complementary to the NLP perspective, this paper provides an HCI perspective on automatic text simplification that systematically analyses who the stakeholders of such technical systems could be and what they need. Technologies like syntactic and lexical text simplification have already been applied to support deaf and hard-of-hearing adults who benefit from lexical simplification and who prefer a system with on-demand simplification [3]. A literature review of interface design guidelines for people who struggle with reading indicates that user interfaces should be simple, clear, and objective [37]. The study also found that users' pains and difficulties need to be considered.

There are several accessible reading tools that specifically target those who struggle with reading. An early exploration of summarization and text simplification tools for people who struggle with reading was provided by Margarido et al. [66]. They found that the simplification approaches that were available in 2008 did improve text understanding to some extent. A related tool is provided by Watanabe et al., who introduced Facilita, an early example of a tool that provides shorter and simplified versions of text content [97]. In another publication, Watanabe et al. explored ways to adapt web content via labeling named entities and replacing difficult words via synonyms [96]. With a focus on mobile interfaces, Medhi et al. conducted an ethnographic study of people who struggle with reading [68]. Their results from 2011 showed that text interfaces were unusable by first-time low-literacy users. They also found that text interfaces are error-prone for users who are literate but inexperienced with an interface. These findings connect to Munteanu et al., who report on the challenges of supporting adult literacy [72]. The challenges they identified include the different literacy levels of users, research bias, irregular attendance of participants, different levels of engagement, and the importance of proxy support.

Overall, our overview of related work shows an important research gap regarding the user experience of accessible text and the perspective of all stakeholders, especially with respect to which tools and interfaces are helpful, who would benefit the most, and in which scenarios such tools are especially useful.

3 METHODS

The review of related work showed that although some promising technical approaches exist, it is unclear in what scenarios accessible text is most needed (RQ1), who would benefit from accessible tools the most (RQ2), and what tools are perceived as helpful (RQ3). It is also an important open question what the interface of such tools should look like (RQ4). To answer these research questions, we performed two studies. In Study 1, we conducted semi-structured interviews with a broad range of experts to collect proposals for accessible text tools. In Study 2, we conducted a survey to elicit which of the proposals from Study 1 are perceived as useful by the stakeholders. This methodological approach allowed us to understand the scenario in which accessible text tools would be helpful and who would benefit the most (Study 1) while directly involving stakeholders (Study 2), which is crucial to building effective systems [48]. With two studies, we elicit which accessible text tools (RQ3) are helpful in which scenarios (RQ1) and which stakeholders would benefit the most (RQ2). We also examine what the interface of such tools should look like (RQ4).

3.1 Semi-Structured Expert Interviews

For Study 1, we interviewed 18 participants (9 females). Participants for the interviews in Study 1 were recruited using snowball sampling. Since requirements for accessible text were first made mandatory by the German Equal Opportunities for People with Disabilities Act [17], we collaborated with the Central Office for Accessible Information Technology of the State of [Anonymized] in Germany. We started with the leader of this office as a seed for our interviews. She made recommendations for others to interview, who, in turn, made more recommendations themselves. We stopped when people started recommending people we had already interviewed and when we had enough diversity in our purposive sample. Using the personal contacts from our snowball sampling, we contacted the different experts via e-mail.

Focusing on experts was necessary because those whose needs may be most visible may not be those who could benefit the most from the tool. A large number of people with cognitive impairments do already have access to support through caregivers or others. Our goal was to understand how those without such resources can be supported through technology.

Table 1 shows that the interviewed experts worked in one or more of the following fields: plain language, accessibility and technology, linguistics and translation, and special or remedial education. In the recruitment, we made it clear that we searched for people with expertise and experience with accessible tools. Our sample includes special and remedial education experts who know the potential users and their needs very well and can articulate needs that certain users may not be able to articulate themselves. One participant was, for example, involved in the largest study on people with Down syndrome ever conducted. We also included

Table 1: The interviewed experts worked in one or more fields: plain language, accessibility and technology, linguistics and translation, and special or remedial education.

ID	Plain Language	Accessibility & Technology	Linguistics & Translation	Special Education
P01		✓		✓
P02		✓	✓	
P03	✓	✓		
P04	✓			
P05	✓			
P06	✓		✓	
P07	✓			✓
P08	✓		✓	
P09	✓			
P10	✓			
P11	✓	✓		
P12	✓		✓	
P13		✓		✓
P14				✓
P15				✓
P16	✓		✓	
P17	✓		✓	✓
P18			✓	

experts with a strong background in accessibility and technology who knew what is technically possible with contemporary natural language processing tools. One of the participants is, for instance, a manager in a startup that develops automatically checks text for comprehensibility and provides tips on simplifying texts.

All interviews were conducted in German. The interviews were administered via videoconferencing software between October and December 2020 due to the COVID-19 pandemic. We recorded the audio of the interviews and hired a professional transcription service to transcribe the audio. The transcriptions were translated into English using professional translation software. Informed consent and permission to record the audio (in line with the European General Data Protection Regulation) were sought and granted from all participants. The responsible authorities granted institutional review board-equivalent approval before the investigation.

In the semi-structured interviews, we asked experts about the potential of accessible text. We also asked them who they thought would benefit the most from accessible text. In addition to that, we also wanted to know which risks and challenges they associated with texts in accessible text and plain language. A central part of each interview was a hypothetical design exercise in which participants had to imagine a tool that can automatically translate texts from everyday language into accessible text. We asked them to describe who would use the system, in what situations and contexts it would be used, and how it would be used. If participants did not comment on it, we also asked them how such a system should be implemented technically. After that, we asked participants about the opportunities and risks they see in using such a system.

We performed a thematic analysis of the transcribed interviews. We identified themes and concepts in an iterative process of inductive coding by moving back and forth the empirical material several times. The codes were merged and split as needed following

axial coding principles [23] and thematic analysis [15]. After the initial assignment of potential themes, the different codings were reviewed repeatedly to ensure that the themes corresponded to the interviewees' statements. The different codings were grouped into themes and subthemes. We iterate over these themes and subthemes several times. The different themes, as well as individual codings, were discussed in weekly videoconferencing sessions. The first author performed the coding. The second author reviewed the results section and checked the plausibility and fit of each coding and the validity of the different themes. Disagreements were resolved by consulting the source material and discussing a case until unanimous agreement was found.

3.2 Stakeholder Survey

After analyzing the findings from Study 1, we conducted a survey targeting individuals with cognitive impairments and non-native readers. In the survey, we presented the accessible text tools and the scenarios from Study 1 to the potential stakeholders. The scenarios included (1) finding information about an upcoming election (Public Administration), (2) receiving a bill from a doctor (Medical Domain), and (3) understanding the COVID-19 rules and restrictions (Everyday Life). We explained the three scenarios in detail. For instance, to introduce the first scenario, we wrote: " Please imagine the following situation: You get a 10-page text with a lot of information about the next federal election. You want to find out the following things: Can I vote? Where can I vote?" We then told the respondents we want to build a technical support system to help them with this task. Participants then rated their agreement on a 5-point Likert scale for each of the tools proposed by the domain experts. They were also asked to choose an answer for the question "I would find it good if I could use the technical support system by". Answer options were again based on the expert proposals. We also asked participants how often they have experienced these situations. Answer options included "Never", "Very rarely", "Rarely", "Occasionally", "Frequently", and "Very Frequently". After that, participants were presented with the accessible text tools proposed by experts (RQ3). They rated the helpfulness of each of these tools on a 5-point Likert scale for each scenario. In addition, participants completed the sentences "I would like to be able to use the technical support system by". They were able to select each of the interfaces proposed by experts. We also asked participants about their background, i.e., their age, gender, education, mother tongue, and whether they have learning difficulties. We also include Others as a reference group.

The survey was conducted in German. A central challenge was surveying those who struggle with reading. Since some of the questions were potentially hard to understand, we recruited our participants through organizations supporting those who struggle with reading. We relied on those existing support networks to ensure that the participants could understand the tools and the survey. This approach maximized the likelihood that those who struggle with reading could complete the complex survey questions on their own or with the support of caregivers or other helpers. This procedure introduced a bias, i.e., we likely did not reach people with all levels of reading difficulties equally. This sampling approach did, however, allow us to reach people we believe to benefit from accessible text tools.

We recruited the participants by sending out e-mails to 89 individuals and organizations. We also asked participants to share our survey with their social networks. We contacted 30 individuals and organizations whose work is focused on People With Cognitive Impairments. We collected the e-mail addresses via Google's search engine using keywords like curative education, social therapy, sheltered workshops, and assisted living providers (in combination with the name of our city). To reach Non-Native Readers, we compiled a list of 43 organizations and individuals using keywords like refugee, immigrant, and expat (and the name of our city). We also contacted 15 of the experts from the interviews who agreed to share the survey with their network. The call for participation was also shared via three newsletters that target People With Cognitive Impairments and one newsletter that targets refugees as one of the largest subgroups of Non-Native Readers in Germany. We used the mailing list of our university's Computer Science and Mathematics department to reach highly educated people without impairments and international students as an important subgroup of Non-Native Readers.

For each survey questions, we explained how the data will be analyzed and informed participants that their data is secret and anonymous. The question "What is the gender you identify with?" was explained as follows: "We use the information to see whether we have surveyed people with different gender identities." We grouped the participants based on their responses to the question: "Which of the Following Points Applies to You?". Answer options included having learning difficulties, Down syndrome, other mental impairments, difficulties with reading and writing, difficulties with communication, dementia, concentration difficulties, and eye problems. We also asked participants whether they are on the autism spectrum, whether they have a mother tongue other than German, and whether they answered as a caregiver/helper or professional. Participants were able to select more than one checkbox. Participants could also select "None of the Points Apply to Me".

Institutional review board-equivalent approval was granted before the investigation. We followed the European General Data Protection Regulation and informed participants about their rights. At the start of the investigations, we clarified that participation is voluntary and that participants can stop the survey at any time.

One hundred ninety-five participants (119 female) completed the survey. We excluded 20 participants who self-reported that they were distracted or gave meaningless responses during the study or because they did not reconfirm their consent at the end of the survey.

The responses of 175 participants (106 female) were used for the analysis. These participants came from three groups: People With Cognitive Impairments (53 participants, 27 female), Non-Native Readers of German (54 participants, 35 female), and Others (88 participants, 58 female). People With Cognitive Impairments includes people who have learning difficulties (15), other mental impairments (7), people in the autism spectrum (3) as well as people with difficulties with communication (14), concentration (27), and reading and writing (16). As noted before, the categories People With Cognitive Impairments and Non-Native Readers are not mutually exclusive. Thirteen people (8 female) reported having an impairment and did not speak German as a first language. The category Others includes those who work as caregivers (43) and those

who selected none of the impairments mentioned by the experts in Study 1 (46). This group was highly educated since caregivers receive special training in Germany and since we recruited them through our university, thus providing an interesting complement to the other two groups.

The average age of all participants was 36.64 (SD=14.85) years. The youngest participant was 18; the oldest was 80. We excluded two participants from this calculation who entered their age incorrectly, but we kept their responses. The average age of People With Cognitive Impairments was 35.48 years (SD=13.34). For Non-Native Readers of German, the average was 30.25 (SD=12.41), for Others it was 41.51 (SD=15.04).

4 RESULTS FROM EXPERT INTERVIEWS

In the following, we will report in which scenarios accessible text would be especially useful (RQ1) and who experts believe could benefit the most from accessible text tools (RQ2). We also report the different accessible text tools that the experts proposed (RQ3) and provide insights into what the interface of these tools should look like (RQ4).

4.1 In Which Scenarios Are Accessible Text Tools Especially Important? (RQ1)

The experts recognized scenarios in which accessible text tools are especially beneficial: Public Administration, Everyday Life, and the Medical Domain.

4.1.1 Public Administration. The most frequently mentioned scenario is Public Administration (P02, P03, P04, P05, P07, P09, P14, P17). Examples of this include forms, notices, general orders (P17), official websites (P14, P17), and tax notices (P02). Experts also referred to child benefits (P02, P05), training assistance (P02), and assistance plans for people with impairments (P09). Other examples include naturalization assistance for immigrants (P02), work permits (P07), unemployment benefits or welfare benefits (P02), and applying for a new ID card (P14). Experts also commented on the role of elections in relation to the government. Election-related texts include information on the ballot (P10), explanations of the election procedures (P05), as well as information about the election program of the different parties (P02, P05).

4.1.2 Everyday Life. Experts also commented on scenarios in Everyday Life (P05, P08, P10, P14, P15, P17), e.g., receiving mail from an electricity supplier (P05), or encountering news on TV or in a newspaper (P10, P14, P15), e.g., about COVID-19 rules and restrictions (P10). Other examples include searching for knowledge online (P10). Experts also discussed tasks like buying things online (P15), buying tickets for a bus, train, or airplane (P10, P15), reading manuals (P08, P15), or understanding legal texts (P09, P16).

4.1.3 Medical Domain. According to our experts, the Medical Domain would also benefit from accessible communication (P01, P02, P04, P07, P08, P16, P17). They mentioned examples like doctor-patient communication (P04, P07) and health information (P01, P17). Examples in this domain also included leaflets or package inserts for medicines (P08) and information regarding health insurance (P02).

4.2 Who Could Benefit From Accessible Text Tools? (RQ2)

The 18 experts identified three stakeholders groups who benefit from accessible text tools: People With Cognitive Impairments, Non-Native Readers, and Everybody.

4.2.1 People With Cognitive Impairments. The largest group of stakeholder are people with cognitive impairments or learning difficulties (P01, P03, P05, P07, P09, P10, P11, P12, P13, P14, P15, P16, P17). Since "far too little information" is available to them, P17 thinks that people with learning impairments, who "just need" to access information, are the core target group. P01 refers to laws that define people with cognitive impairments as the target group of Plain Language [17].

Relevant subgroups include people with Down syndrome (P15), learning, cognitive or intellectual impairments (P05, P09), and people with mental development disorders (P03, P09, P14). However, P16 also pointed out that people with cognitive impairments may not need support because they have caregivers who do the text work with and for them. P16 does, however, recognize situations where the degree and severity of the impairment are not so severe and where solutions may be helpful.

In addition to learning difficulties, the experts also mentioned many other impairments (P01, P02, P03, P04, P05, P10, P14, P15, P16, P17, P18). P04 defined the target group as "all those who have problems with the regular offer". Impairments include reading and writing difficulties (P02, P03, P05, P09, P14) and dyslexia (P05). Experts also discussed communication barriers (P16) and the challenges that people in the autism spectrum face (P14, P15), e.g., when encountering metaphors, irony, or rhetorical questions. In addition to that, P14 points to reading and language difficulties that are "below the radar", e.g., because they have not been diagnosed yet.

4.2.2 Non-Native Readers. Another big target group recognized by experts are Non-Native Readers (P01, P02, P05, P06, P07, P08, P09, P10, P12, P13, P16). While most experts referred to Non-Native Readers in the context of immigration, P08 highlighted the role of tourists who, e.g., visit a museum and enjoy "small experience in the foreign language" that they learned. P09 argues that Non-Native Readers are confronted with the exact same issues as People With Cognitive Impairments. According to P05, the number of Non-Native Readers, e.g., due to migration, is also much larger than the group of People With Cognitive Impairments. P02 highlights that Non-Native Readers with an immigrant background "simply don't dare to communicate because they are afraid". P03 highlighted an important difference between People With Cognitive Impairments and Non-Native Readers. For instance, somebody with a learning impairment may have a much larger vocabulary than somebody who just learned his first 500 words.

In addition to recognizing that everybody benefits from accessible text, it is also important to highlight the intersectionality of the other two groups. As discussed, the Living With Low Literacy 2018 study found that in Germany, 0.60% of citizens are illiterate and 11.50% are functionally illiterate [35, 36]. Of those who are illiterate or functionally illiterate, 47.4% grew up with a first language not German. Therefore, the different categories are not mutually

exclusive, i.e., many People With Cognitive Impairments may also be Non-Native Readers.

4.2.3 Others. In line with the ideals of universal design, a large group of experts argued that accessible text is useful for everybody (P01, P02, P03, P05, P07, P08, P14, P16, P17, P18). P05 and P07 even argued that "you can't have a target group" because people "are all different" (P05) and the number of people that could benefit is "huge". Based on her circle of friends, P17 discusses a large number of people without impairments who use plain language because it is quick and easy to read and delivers the "information you want immediately on demand". P14 also believes that while it is important to have people with cognitive impairments in mind and think about them, especially considering administrative language, "it is usually everybody who benefits". P08 thinks that if a barrier is removed, regardless of who it is for, this is always good. P07 compares this to low-floor buses. While they primarily target wheelchair users, they are also great for senior citizens. He, as a young man without impairments, also benefits from such buses because he "can just jump in".

4.3 Which Accessible Text Tools Are Useful to Stakeholders? (RQ3)

In the following, we will present the accessible text tools proposed by experts. We grouped these tools based on whether they are about (1) Compressing, (2) Extending, (3) Experiencing, and (4) Reviewing Text.

4.4 Compressing Text (RQ3)

In the "Compressing Text" category, we find proposals for tools that summarize and prioritize text. This category also includes tools for lexical simplifications and tools that automatically reduce the reading volume.

4.4.1 Summary and Prioritization. A large number of participants commented on the importance of summarizing text and prioritizing information (P02, P04, P07, P10, P14, P16, P17). P01 highlights the importance of identifying the core statements of a text. P17 argues that summaries that filter the core statement are necessary for some texts. P02 thinks it would also be helpful if the tool could identify tasks formulated in the text, e.g., that the recipient of a letter must write an e-mail to a certain person. P01 highlights important risks associated with summarizing or prioritizing information. She asks, "Who defines the core message?" P04 warns that the coherence of a text may be negatively affected by summaries. P05 argues that it could be stigmatizing if a text in plain language does not include everything in the original. He criticizes that this would mean that information "is being withheld".

4.4.2 Lexical Simplifications. Another way of making text more accessible is lexical substitution (P03, P06, P10, P18). P05 believes that there are complex or foreign words in German that can be conveyed much more easily. P03 and P06 imagine a system that makes several suggestions to see which word is the most suitable in a particular context. P18, for instance, argued that it would be helpful to provide "alternative words", e.g., based on a thesaurus. P10 envisioned an interface highlighting all words that could be a "source of unrest". P03 thinks that the system could also help disambiguate the different meanings of a word and help users or authors decide which simplification to choose. Similarly, P08 proposed a tool that analyzes whether a particular demographic understands certain words.

4.4.3 Reduce Reading Volume. Another aspect that many experts commented on is keeping the reading volume low (P02, P03, P04, P07, P10, P14, P16, P17). P16, for instance, cites making sure that texts do not become too long as one of the challenges translators face. P04 also argues that it is a big challenge to keep the amount of text generally low or at a manageable level for readers with reading difficulties. P14 thinks the goal is to abstract things and say more with fewer words. P03, however, warns that shortening a text means that the linguistic complexity of such text is even more compressed because the text contains more information. P17 is worried that modified texts could become too long because it is hard to recognize a text's core message.

4.5 Expanding Text (RQ3)

The "Expanding Text" category includes tool proposals that help users find explanations of difficult words, and tools that can improve the structure and flow of a text.

4.5.1 Explanations. A large number of experts commented on explanations that can make texts more understandable (P01, P02, P05, P10, P16). P01 describes this as providing examples to explain a context better. P02 argues that it is important to ensure that readers understand what a text is trying to convey, e.g., whether it tries to inform a reader or is advertising something. P14 argues that for specific "abstract terms", it is necessary to convey all that is "hidden behind this term". For this, interviewees described a tool that provides explanations for terms (P18, P10, P16). P15, however, warned that explanations that the user does not need could make the reading more difficult.

4.5.2 Structure and Flow. Experts also referred to a tool that improves the structure of a text (P03, P04, P07, P17). P03, for instance, argues that the sentences of a text may not be in the optimal order. P03 believes that sorting the sentences logically and avoiding jumping back and forth would be beneficial for reading. This insight connects to P04, who thinks that the main task of professional translators like herself is to "bring structure into the texts so that the reader can follow it logically". She reports that there are "a lot of bad original texts that only tell you at the end of the text what it is actually about". Despite her interest in this solution, P03 worries that making connections between sentences and achieving a coherent text with a "common thread" is difficult to automate and that a lot can go wrong.

4.6 Reviewing Text (RQ3)

The "Reviewing Text" category encompasses the need for tools that facilitate quality checks and reviews by the target group.

4.6.1 Quality Check. Several experts commented on tools that act as a quality check (P03, P06, P07, P08, P11, P12, P13, P17, P18). P03, for instance, thinks that a tool should check whether a text

is consistently worded and presented in a simple and understandable manner. She hopes such a tool could make quality checks as commonplace as spelling and grammar checks. P06 describes a tool that provides an overview of aspects that inhibit comprehension of texts. The tool would, for example, mark all instances of passive text in yellow. All passages that may contain technical terms could be marked in orange. P07 proposed a tool that analyses a text and suggests what should be improved to achieve a certain level of comprehensibility.

4.6.2 Reviews by Target Group. Experts also commented on the importance of having the output of a translation evaluated by stakeholders and how tools can support this (P01, P04, P05, P10, P13, P14, P16, P17, P18). P01 and P14 argued that it is important to present texts to stakeholders like people with learning difficulties and ask them: "Did you understand that?". P05 believes that there is no way around such reviews. P02 thinks that the target group should frequently review the texts. P06 argued that the ideal reviewer comes from the target group and has expert knowledge about the text's topic. Some experts like P04 and P13 already involve the target group as "co-researchers", who review the texts produced by their companies. However, other researchers like P07 and P14 criticized this approach. P07 is worried that reviewers will learn with experience. He believes that at some point, they "are probably just too good to judge a text in easy language". P09 also argues that "of course, they [the reviewers] learn". P07 and P14 also warned that reviews are not representative. This may, however, not be a problem in practice. P13 argues that the reviewers in her project were able to assess the comprehensibility of a text both for their own demographic and other target groups. P04 also highlights that reviews occur in a professional setting where everybody is aware of his or her role. She thinks that such reviews have only advantages and no disadvantages. Based on her practical experience, P04 thinks that such reviews are "very, very useful" even though it can be challenging to find reviewers (P04, P09).

4.7 Experiencing Text (RQ3)

In this category, we do not find concrete tools, but important requirements for tools related to "Experiencing Text". This category includes visual factors related to the interface. This category also relates to ways of avoiding users' stigmatization and enabling the personalization of texts and tools.

4.7.1 Visual Factors. P01, P02, P10, and P12 commented on visual factors like illustrations. P02 discussed how important it is to present the simplified text in a visual format that is accessible, that has pictures, and that uses the right font and the right contrast. P10 emphasizes that it is not only about the text but also about illustrations and font size. P02 warns that this visual perspective is frequently disregarded because many of the practitioners in the field have a background "in print". P01, however, warns that illustrations can make it possible to recognize a text as plain language without consulting the text. She believes that this can lead to stigmatization. She argues that it "must not be noticeable at all" that a text was modified.

4.7.2 Stigmatization. Another important experience factor discussed by several experts is ensuring the system does not stigmatize people (P05, P06, P07, P09, P10). P10, for instance, believes that it is important to provide people with user interfaces and descriptions that are not defect-oriented, exclusionary, or defamatory. She does not want people to feel that they are not taken seriously. P05 criticizes that accessible language is currently presented in a way that treats users as children or marks them as people with a visible need for support. P07 and P09, therefore, also warned against using infantile or children-like language or illustrations. According to P06, typographic markers pose the risk of evoking negative connotations. P06 urges designers and developers to exercise caution when marking things as more understandable because this could scare off people.

4.7.3 Personalization. Experts also commented on the importance of personalizing tools for stakeholders (P03, P05, P07, P11, P13, P15, P17, P18). P15 highlights the importance of finding technical solutions for very individual situations to reach those strongly impaired. P07 thinks it would be great if the "AI" could "learn" what simplifications a user needs and likes. P13 describes such adaptive interfaces as "supporting the user according to his or her current needs".

4.8 What Should the Interface of Accessible Text Tools Look Like? (RQ4)

In addition to identifying scenarios (RQ1) and stakeholders (RQ2) for accessible text tools (RQ3), we also examine what the interface of such tools should look like (RQ4).

4.8.1 Photo-Based Smartphone App. Several experts discussed the potential of a mobile app as an interface (P06, P07, P10, P14, P15). P07, P14, and P15 proposed variations of an app where the user holds a text in front of the camera of a smartphone and where the app then reads out the result. For P14, this "little dream app" would enable users to take a picture, mark a passage the user didn't understand, and then have the app translate it. P15 described this as the best possible solution.

4.8.2 Software Extensions. P03 believes that a broad range of interfaces could be useful, including extensions of word processors, Web browser plug-ins, or dedicated websites. She highlights that websites have the advantage of being very easy to use. P05 thinks that accessible text tools should be integrated into a web browser. P06 believes that a solution integrated into a browser is the easiest, nicest, and most user-friendly. P10 envisioned an interface similar to spell-checks available in word processors.

4.8.3 Voice Input & Output. Considering a scenario like a supermarket, P10 believes that audio feedback might be the most helpful. She argues that with audio feedback, it is not noticeable that a user relies on support, which could make it less "embarrassing" for the user. P15 also thinks it would be best if users had a speech interface where they can enter text verbally and receive audio feedback. He believes that people would be "incredibly helped" by such personalized interfaces.

4.8.4 Chatbots. Experts also mentioned chatbots as an important interface (P01, P02, P09, P16). For P09, a chatbot could provide a "personal consultation" and take the user "by the hand". P02 and P16 imagine asking a chatbot what a certain form is about. According

to P01, chatbots could enable the target group to give feedback on whether a text is understandable or not.

4.8.5 Physical Scanner. P01 and P02 imagine a physical device akin to existing screen readers for blind people. With the device, a text could be automatically digitized, e.g., by placing a letter under a scanner. The device would then recognize the text and provide a "beautifully barrier-free" (P02) and simplified text as output. This text could also be enhanced with illustrations. P02 believes that such a "very old-fashioned" approach based on a physical device on a table could be particularly helpful for people who are not so "technophile".

5 RESULTS FROM SURVEY

Study 1 yielded several tool proposals that can make text more accessible. In the following, we validate the proposals from the expert interviews with a survey of stakeholders. We report how the different scenarios (RQ1) are perceived by stakeholders (RQ2) and which of the different accessible text tools they consider to be helpful (RQ3), and how the interface should look like (RQ4). Based on the results of Study 1, we surveyed People With Cognitive Impairments and Non-Native Readers. We describe the methods and the participant sample in Section 3.2.

In this section, we report the results from Study 2 on how stakeholders perceive scenarios (RQ1+RQ2). We also compare the helpfulness of the proposed accessible text tools by stakeholders (RQ2+RQ3) and scenario (RQ1+RQ3). In addition to that, we present results on what interfaces for accessible text tools (RQ4) are preferred by the stakeholders.

5.1 How Stakeholders Perceive Scenarios (RQ1+RQ2)

With the survey, we investigated how common the different scenarios proposed by the experts are. As explained, we focused on the three scenarios mentioned by experts: Public Administration, Medical Domain, and Everyday Life. Figure 1 provides an overview of how familiar the participants were with each scenario. The results show that all scenarios are familiar to the majority of stakeholders.

The Public Administration scenario is encountered by 68% of the participants sometimes or more frequently than sometimes, including 85% of People With Cognitive Impairments, 54% Non-Native Readers, and 67% of Others. 43% of People With Cognitive Impairments experience this scenario frequently or very frequently. An explanation why only 54% of Non-Native Readers have experienced this scenario focused on voting could be that Non-Native Readers may not be eligible to vote in Germany.

The Medical Domain scenario, where a user receives mail from his or her doctor, was encountered even more frequently. 75% of the participants experienced this scenario sometimes or more frequently, including 72% of People With Cognitive Impairments, 67% Non-Native Readers, and 82% Others. More than half of People With Cognitive Impairments (53%) experience this scenario frequently or very frequently, compared to 41% of Non-Native Readers and 44% of Others. It is especially noteworthy that all People With Cognitive Impairments (100%) have experienced this scenario.

The most frequently encountered scenario, by far, is the Everyday Life scenario, where people are confronted with COVID-19 rules and restrictions. 90% of the participants experience this scenario at least sometimes, including 94% of People With Cognitive Impairments, 83% of Non-Natives, and 91% of Others. 50% of Non-Natives and 77% of People With Cognitive Impairments experience this scenario frequently or very frequently. We again found that all People With Cognitive Impairments (100%) have experienced this scenario. 78% of People With Cognitive Impairment experienced situations where they had to figure out whether COVID-19 rules and restrictions apply to them frequently or very frequently.

Overall, the survey confirmed that the scenarios (RQ1) proposed by the experts are familiar and relevant to most stakeholders (RQ2).

5.2 Helpfulness of Accessible Text Tools by Stakeholders (RQ2+RQ3)

Figure 2 provides an overview of how the different accessible text tool (RQ3) are perceived by the stakeholders (RQ2).

The vast majority of People With Cognitive Impairments perceived the Summarization of Key Messages (93%) as helpful. More than three out of four also found Explanation of Difficult Words (78%) would help them. Other helpful tools include Reducing the Length of a Text (72%) and Finding Alternatives for Difficult Words (67%). Overall, we find that all but two tools are perceived as helpful by a majority of People with Cognitive Impairments. Even these two tools are popular with many People With Cognitive Impairments. 48% want the Different Meanings of Words Explained and 43% appreciate an Improved Font and Font Size.

The ratings of Non-Native Readers are similar to those of People With Cognitive Impairments. Here, too, the vast majority of respondents (91%) considered the Summarization of Key Messages to be the most useful tool to make text more accessible. The second most helpful tool would provide Explanations for Difficult Words (80%), followed by Alternatives for Difficult Words (76%), and a tool that Reduces the Length of a Text (72%). For Non-Native Readers, there is also one tool that only every third Non-Native Reader (28%) considers helpful: Improving Font and Font Size.

The same ranking emerged with Others, i.e., caregivers and people without impairments. The Summarization of Key Messages is considered to be the most helpful tool (93%), followed by Reducing the Length of a Text (73%) and Providing Explanations for Difficult Words (73%). The least helpful tool Explains The Different Meanings of Words (45%).

The results show that most accessible text tools (RQ3) are perceived as helpful by the different stakeholders (RQ2). Again, the Summarization of Key Messages stands out because it is recognized as highly helpful by all stakeholders.

5.3 Helpfulness of Accessible Text Tools by Scenario (RQ1+RQ3)

Next, we examine whether the accessible text tools (RQ3) are perceived differently based on the usage scenarios (RQ1): Public Administration, Medical Domain, and Everyday Life (Figure 3). For this, we combined the ratings of the different stakeholders.

In the Public Administration scenario, we find that the Summarization of the Key Messages is perceived as most helpful (91%), followed by Reducing the Length of a Text (74%), and Providing

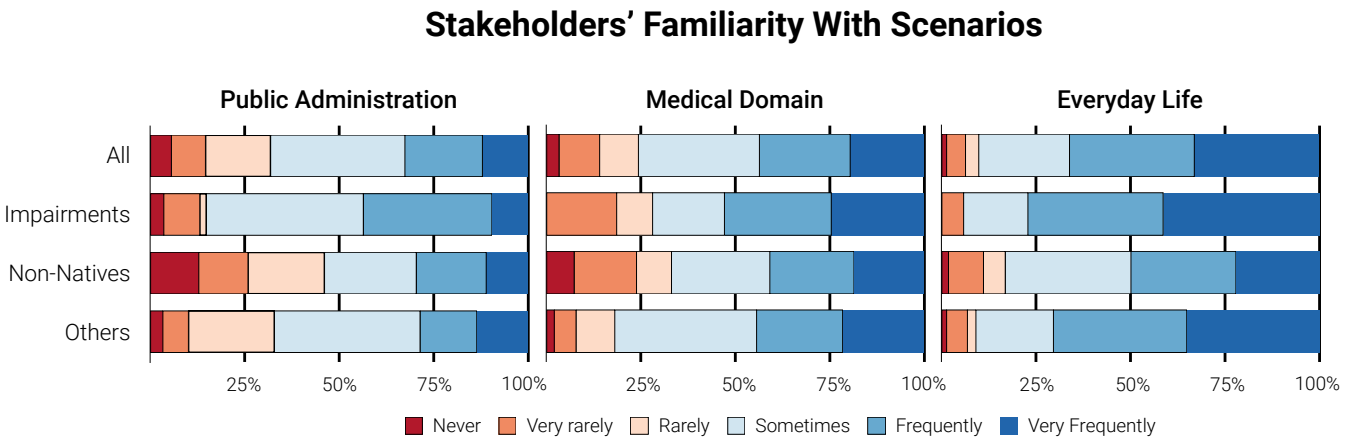

Figure 1: For each of the three scenarios proposed by the experts, we asked People With Cognitive Impairments, Non-Native Readers, and Others whether they are familiar with the scenario.

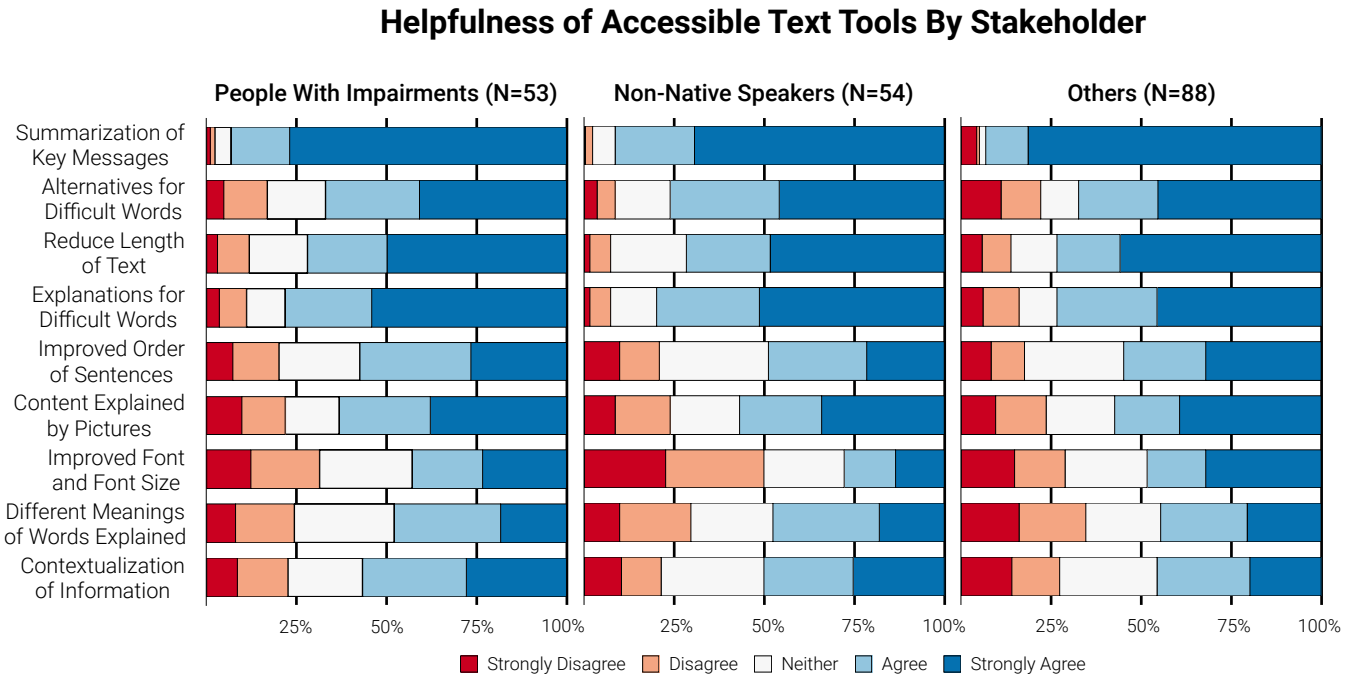

Figure 2: For each of the accessible text tools proposed by experts, we evaluated whether members of the three target groups – People With Cognitive Impairments, Non-Native Readers, and Others – considered them helpful.

Explanations for Difficult Words (71%). The least helpful tool for this scenario is explaining the Different Meanings of Words (43%).

In the Medical Domain scenario, where users receive a letter from their doctor, the Summarization of Key Messages is again perceived as most helpful (93%). This tool is followed by Providing Explanations for Difficult Words (90%), Providing Alternatives for Difficult Words (78%), and Reducing the Length of a Text (63%). The least helpful recommendation in this scenario is Improving the Font and the Font Size (40%).

In the Everyday Life scenario, where users are confronted with changing COVID-19 rules and restrictions, the Summarization of Key Messages is again perceived as most helpful (90%). The second most helpful component is Reducing the Length of a Text (74%), followed by Providing Explanations for Difficult Words (65%) and Explaining Content by Pictures (64%). Again, the least helpful tool is Improving the Font and the Font Size (42%).

Our results indicate that the accessible text tools (RQ3) are not only perceived as helpful by all stakeholder groups (RQ2) but also

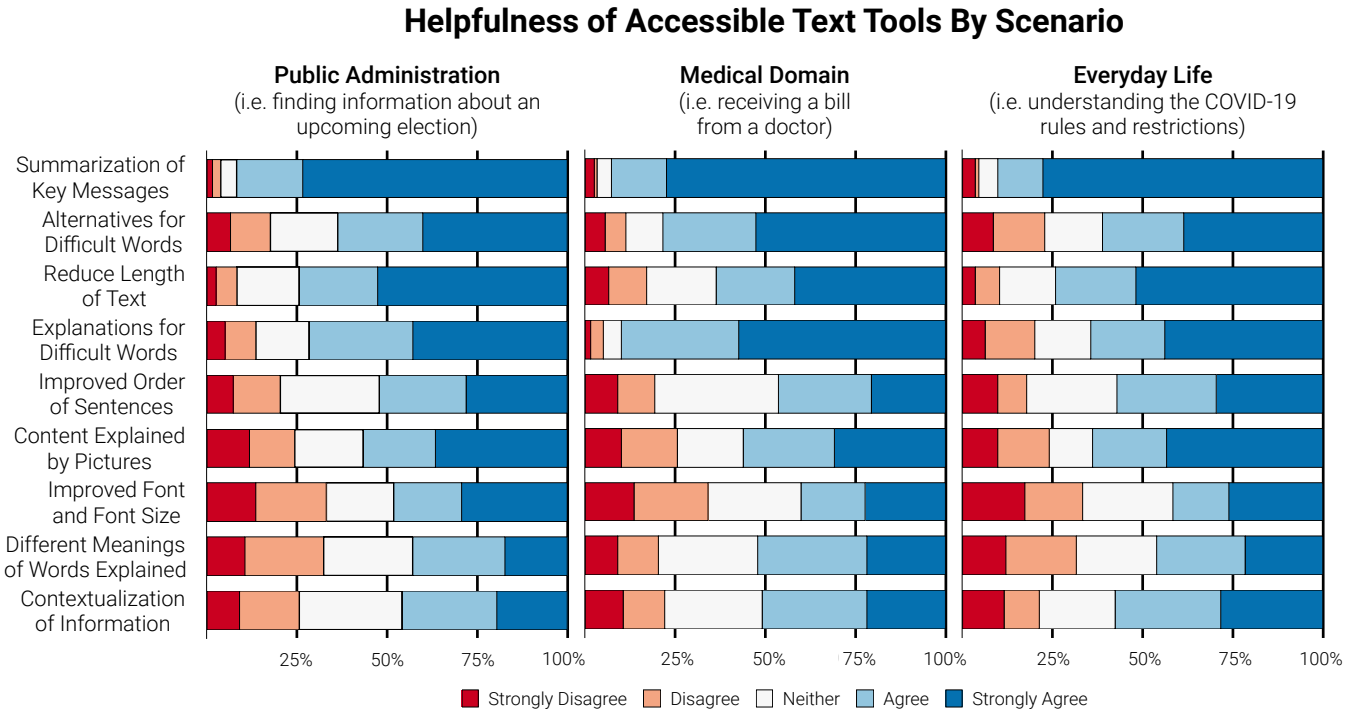

Figure 3: For each of the accessible text tools proposed by experts, we evaluated whether users considered them helpful in the scenarios proposed by experts. Scenarios included finding information about an upcoming election (Public Administration), receiving a bill from a doctor (Medical Domain), and understanding the COVID-19 rules and restrictions (Everyday Life).

across the different scenarios (RQ1). Our investigation shows that the Summarization of Key Messages is recognized as the most helpful tool in all scenarios.

5.4 Interfaces for Accessible Text Tools (RQ4)

We also asked stakeholders which interface they prefer in which scenario (RQ4). The interface options were based on the findings from Study 1 The options included a Photo-Based Smartphone App, a Chatbot, a Physical Scanner, Voice Input & Output, a Browser Extension, and a Word Processor Extension.

For the Public Administration scenario, 39.43% of people selected the Browser Extension, followed by the Photo-Based Smartphone App (21.71%) and a Word Processing Extension (12.00%). People with Impairment also ranked the Browser Extension the highest (33.96%), followed by the Photo-Based Smartphone App (26.42%) and the Voice Input & Output (11.32%). For Non-Native Readers, the highest-ranked Browser Extension (37.04%) is followed by the Photo-Based Smartphone App (20.37%) and the Word Processing Extension (18.52%). For Others, the Browser Extension is again the most preferred (35.23%), followed by the Photo-Based Smartphone App (23.86%) and the Word Processing Extension (14.77%).

In the Medical Domain scenario, where a user receives a letter from his or her doctor, 42.86% of the participants perceive the Photo-Based Smartphone App as the most helpful interface. 16.57% of people favor the Browser Extension, and 14.86% like the Chatbot best. Non-Native Readers (51.85%) have a much stronger preference for the Smartphone App than People With Cognitive Impairments (43.40%) and Others (42.05%). For People With Cognitive Impairments, the Browser Extension is ranked second (22.64%), and the Voice Input & Output and the Word Extension share the third rank (9.43%). For Non-Native Readers, the Browser Extension is second (14.81%), and the Chatbot is third (12.96%). For Others, the Chatbot is second (18.18%), and the Browser Extension is third (10.22%).

In the third scenario based on an Everyday Life scenario, we again find that a Photo-Based Smartphone App is the preferred interface across stakeholders (42.29%). People With Cognitive Impairments (47.17%), Non-Native Readers (44.44%), and Others (42.05%) all liked this interface the best. For People With Cognitive Impairments, the Browser Extension is ranked second (22.64%), and the Voice Input & Output is ranked third (11.32%). For Non-Native Readers, the Browser Extension and the Voice Input & Output are both ranked second (22%). For Others, the Browser Extension (17.05%) and the Chatbot (17.05%) are ranked second.

Our findings indicate that the right interface depends on the usage scenario. Overall, the Photo-Based Smartphone App and the Browser Extension are recognized as the most helpful interfaces (RQ4).

6 DISCUSSION

This paper explores tools that make text more accessible. We identify who (RQ2) could benefit in which scenario (RQ1). We also propose and validate several accessible text tools (RQ3) and show what the interface of such tools should look like (RQ4). Knowing answers to these questions is an important first step toward making text more accessible. Our mixed-methods investigation showed that the scenarios proposed by experts were scenarios that many of the stakeholders were familiar with. Seven out of ten participants experience the Public Administration scenario at least sometimes. Nine out of ten experience the Everyday Life scenario sometimes, frequently, or very frequently. We also found that the survey respondents did perceive the different tool proposals as helpful in the scenarios, especially when trying to understand COVID-19 rules and restrictions. Our investigation also shows that it is not only People With Cognitive Impairments or Non-Native Readers who experience the scenarios and who view the accessible text tools as helpful but that everybody would benefit. Many users could benefit from accessible text tools in the three scenarios: Public Administration, Medical Domain, and Everyday Life.

In the following, we summarize our findings, describe the Accessible Text Framework to guide the design and development of accessible text tools, and discuss how it can be implemented using contemporary natural language processing techniques. We also summarize the open challenges associated with accessible text tools.

6.1 What Accessible Text Tools Could Look Like

The investigation showed that the most helpful tool across scenarios and stakeholders is the Summarization of Key Messages. This tool was regarded to be the most helpful in all scenarios and by all stakeholders. In prior work, text simplification is often framed as a translation task from everyday language to "plain language", akin to a system that translates from English to French. Informed by such prior work [25, 52, 74, 80, 91, 101], we expected the simplification task to be primarily focused on end-to-end translations from more complex to more simple language. Our investigation suggests that sentence-by-sentence translations might not frequently be what stakeholders need or want. Several experts even argued that sentence-by-sentence translations are impossible or unwanted (P05, P14, P01, P04, P12). P10, for instance, thinks that the "translation" is not a simplification, but an effort to make something more understandable. P04 and P16 describe the challenge that translators face as filtering the relevant information and extracting what needs to be explained further (while ensuring that the texts do not become too long). Other helpful tools include Explanations of Difficult Words, Reducing the Length of a Text, and Providing Alternatives for Difficult Words.

Our mixed-methods investigation showed that two different interfaces are preferred: the Photo-Based Smartphone App, especially in the Medical Domain and the Everyday Life scenarios, and the Browser Extension, in particular in the Public Administration scenario. These findings corroborate related work like Liebling et al. on how immigrants as Non-Native Readers use translation software like Google Translate. They found that seven of nine immigrants use Google Translate's camera/scan translation, e.g., in shopping scenarios and to scan documents like utility bills [57]. We show that People With Cognitive Impairments and Non-Native Readers in Germany also rated this interface highly. Liebling et al. also found that eight out of nine of their interviewees used the voice input feature. Surprisingly, while Voice Input & Output is also mentioned as an interface, the Photo-Based Smartphone App and the Browser Extension are consistently ranked higher.

6.2 Accessible Text Framework

To guide future research on making text more accessible, we compiled the Accessible Text Framework. The Accessible Text Framework relates the different categories to each other. Tools in the (1) Expanding Text and (2) Compressing Text transform a text into a new version. (3) Experiencing Text relates to tools that affect how text is presented and how the different simplification steps are implemented. (4) Reviewing Text describes tools that facilitate the feedback loop that is used to iteratively improve the text based on feedback from stakeholders.

The visual representation of the framework shown in Figure 4 illustrates the tension between (1) Compressing and (2) Expanding Text and outlines how tools that facilitate (3) Experiencing and (4) Reviewing Text can help designers and developers overcome these tensions. As highlighted by the symbol of a scale, the components of the Accessible Text Framework need to be balanced. Our interviews and survey showed that a balance between making a text as short as possible ((1) Compressing Text) and making a text as long as necessary ((2) Expanding Text) is needed. As our investigation of the different scenarios showed, this balance depends on a text's content and context. It is also highly dependent on the stakeholders of a text. The components in the (3) Experiencing and (4) Reviewing Text categories provide a way to balance compressing and expanding text. The user interface plays a crucial role in how the expansions and compressions of text are presented to users. Our investigation also showed that the decision to expand and compress a text should only be made in close consultation with stakeholders. Our interviews indicate that a promising way to achieve this is by employing people from the target group and empowering them to review the text through computer-supported cooperative work interventions. A positive side effect is that it could create interesting and varied jobs for people with cognitive impairments and non-native readers.

The Accessible Text Framework can be regarded as a technical implementation of the four characteristics of the established Hamburg comprehensibility model [56, 67]. Concision relates to the recommendation to Reduce the Reading Volume from (1) Compressing Text. The linguistic simplicity required by the framework can primarily be found in the (2) Expanding Text category that covers Explanations for Difficult Words and Lexical Simplifications. The motivation characteristic from the Hamburg comprehensibility model is represented by the Personalization aspects of the (3) Experience Text category. The Accessible Text Framework expands the Hamburg comprehensibility model by adding user experience and user interface factors and insights on how to Prevent Stigmatization. In addition to that, we also provide approaches on (4) Reviewing Text via Quality Check Tools and Reviews by Members of the Target Group.

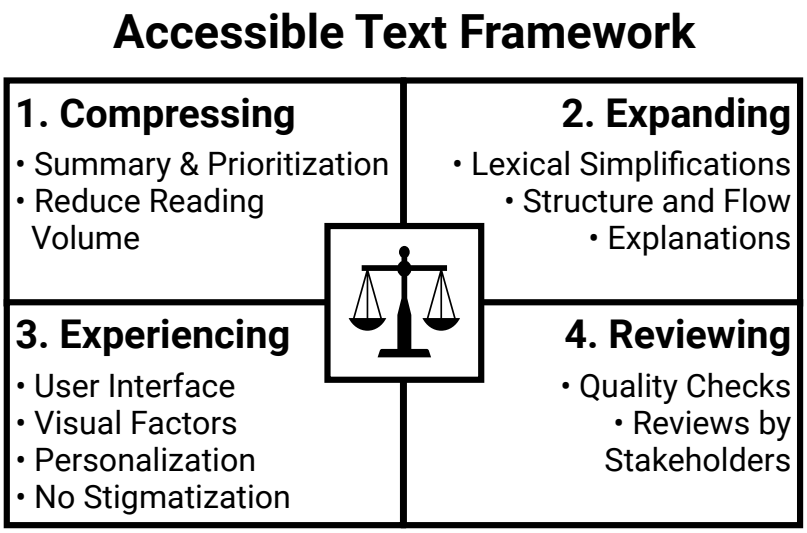

Figure 4: The Accessible Text Framework distinguishes between (1) Expanding, (2) Compressing, (3) Experiencing, and (4) Reviewing Text. This framework systematizes the accessible text tools that we identified in the interviews and whose helpfulness we confirmed with the survey.

6.3 Technical Feasibility Analysis of the Accessible Text Framework

Our investigation unveiled the needs of functionally illiterate people and showed how technology can support them. To guide future research efforts, we will classify the proposed tools based on how much research is still needed until the tools can be used in practice. We distinguish between tools that are available today, tools that are on the horizon, and tools that require further research.

6.3.1 Tools That Are Available Today. The (1) Expanding Text and (2) Compressing Text categories are directly related to existing research on text simplification [25, 52, 91, 101] and text summarization [2, 80]. As our investigation showed, accessible text tools may be more closely related to text summarization than text simplification. Most text summarization approaches are either abstractive or extractive [92]. While extractive approaches retrieve key phrases or sentences, abstractive approaches generate a summary by paraphrasing sections of a source document. Early extractive systems used heuristics and statistical features such as word frequency and distribution [59]. Graph-based extractive systems rely on eigenvector centrality, e.g., TextRank [69] and LexRank [30], generally achieve good summarization results. More sophisticated, attention-based deep learning networks have also been applied to the task [79, 104]. Both abstractive and extractive summarization approaches could be adapted to implement the Summary & Prioritization tool from the (1) Compressing Text category. Prototypes for solutions from the Summary & Prioritization category can be easily implemented, e.g., using techniques like TextRank [69] and LexRank [30], which are available in open-source implementations for many languages. For English, more sophisticated deep learning approaches like Google's Pre-training with Extracted Gap-sentences for Abstractive Summarization (PEGASUS) are also available [104].

Explanations and Lexical Simplifications from the (2) Expanding Text category could leverage existing resources like the Simple English Wikipedia and Hurraki [46], which explain words in plain language. This approach could be expanded using explanations from dictionaries. Tools could use the frequency of a word as a proxy for its complexity. For less common words, a tool could then check whether synonyms, hyponyms, or hypernyms exist that are more frequently used and which can be considered to be widely known. Synonyms, hyponyms, and hypernyms can be extracted from established hierarchies like WordNet [71] (for English) or GermaNet [38] (for German). They could also be learned from data, e.g., via distributional semantics and word2vec [70, 82].

Regarding the User Interface, there is a large body of existing research on making these accessible and as easy to use as possible [21, 33]. Considering Reviews by Stakeholders, there is a lot of knowledge on how to conduct them. The experience of the experts on plain language that we interviewed should be taken into account to implement them [9]. It could be helpful to involve these experts in developing technical tools that facilitate these reviews. The same is true for the Quality Checks, which can be augmented through technology based on the existing processes of these domain experts.

6.3.2 Tools That Are on the Horizon. The overview in the previous section showed that there are a large number of things that can be done today. The technical implementation is, however, only the first step. There are several important open human-computer interaction and computer-supported cooperative work questions that need to be answered to develop accessible text tools that are helpful for many people.

Even though a working prototype of the text summarization tool proposed by the experts can be implemented by adapting

existing NLP and ML research, it will also be important to directly involve stakeholders, e.g., via user-centered design and co-creation [48, 65, 89], to understand how these technologies can and should be adapted. This is especially important since a recent critical evaluation of state-of-the-art neural text summarization systems by Kryściński et al. identifies three important shortcomings of contemporary research: (1) datasets are noisy and leave the task underconstrained, (2) evaluation protocols are only weakly correlated with human judgment, and (3)models overfit to biases [55]. Kryściński et al. argue that progress on benchmark datasets has stagnated, even though the interest in the community and the research on the topic has increased. Investigations with a focus on participatory design could change this.

Regarding Summary & Prioritization, there is also ample research on approaches based on deep learning [55, 79]. Technologies like Generative Pre-trained Transformer 4 (GPT-4) are applied to automatically summarize text [90]. The OpenAI application programming interface even provides an option to "Summarize for a 2nd grader", that can be used to translate difficult text into simpler concepts [76]. The API also provides options to create analogies and generate an outline for a research topic. Such sophisticated text understanding can serve as a starting point to improve the Structure and Flow of texts. Researchers could also explore how systems for argumentation mining can be leveraged to automatically trace the argumentation of a text [18, 86, 95] and how this can be used to improve the structure of a text. Interviews with companies that already translate text to plain language using manual labor could be a starting point for such research. Tools like GPT-4 could be fine-tuned using examples of high-quality plain language translations provided by experts.

In addition to the large number of tools that can be implemented with available technology, several technologies on the horizon could become valuable. There is, for instance, a large body of research on recommendation systems [47] and co-adaption [63] that can be used to guide research on personalization in accessible text tools. Personalized systems can benefit from research on artificial intelligence and machine learning, e.g., on how to compute the similarity between users [41, 54] or the similarity between texts [1, 28]. These technical approaches could be used to infer which tools are particularly helpful for a certain user in a particular scenario. Machine learning systems are, however, complex socio-technical systems that can be challenging to explain [5, 42, 44].

6.3.3 Tools That Require Further Research. Unlike other tools that can build on existing research, tools in the (4) Reviewing Text category require radically new socio-technical solutions. While the Quality Check Tool proposed by experts is similar to existing spell-checking software and writing assistants like Grammarly, empowering People With Cognitive Impairments or Non-Native Readers to review texts is a highly complex, open problem. Due to the complexity of the task and the duality of compressing and expanding text, tools in this space require entirely new interfaces for cooperative work and social computing. It is also an important open question how the (4) Reviewing Text tools can be integrated into workflows and how the stakeholders can be engaged. One possible research direction could be a *GitHub for Accessible Text*, i.e., an integrated socio-technical platform that streamlines the process of expanding, compressing, and reviewing texts. Considering the task's complexity and importance and the different stakeholders' specific requirements, novel social and technical ways of facilitating such reviews should be examined in detail.

Long-term investigations that deeply involve stakeholders are also necessary to understand what Reducing the Reading Volume means in practice and what Visual Factors influence user acceptance. Further research is also needed to understand what interfaces need to look like to avoid the stigmatization of users.

Most importantly, research in human-computer interaction and computer-supported cooperative work is needed to make Quality Checks as effective as possible and to enable Reviews by Stakeholders. This research could follow the example of prior work on misinformation, where the identification of manipulated images online [94] and fact-checks of news stories [40] was supported through online platforms. These investigations looked at how technology can systematize and augment existing processes and how technologies like argument classification can help stakeholders.

There are also open challenges associated with the Summarization of Key Messages tool. The operationalization of a "key message" will vary from scenario to scenario and stakeholder to stakeholder. The same is true for what constitutes a summary. It also remains an open question how long the summary should be and how it can be made transparent which information was omitted and why. Additional research is needed to determine what a good text length is for an individual user for a specific language and a scenario.

6.4 Limitations & Future Work

The primary goal of this paper is to inspire and motivate work on accessible text tools. For this, we combined expert interviews with surveys. The findings of Study 1 are based on a diverse, gender-balanced snowball sample of experts from different fields. Though our snowball sample was seeded with an expert from accessibility, we reached experts with backgrounds in linguistics, technology, special education, and plain language. We validated the findings from the interviews in a large-scale survey with 175 participants. Our investigation is limited by the fact that we focused on perceived helpfulness. Further work is needed to implement the accessible text tools, e.g., as mobile apps or as a browser extension, and to evaluate their helpfulness in user studies. Another limitation of our investigation is that we focused on the three most frequently mentioned scenarios. Of course, many possible variations of the three scenarios and many other relevant scenarios need to be explored.

As described, we focused on people with cognitive impairments who do not have access to support through dedicated caregivers. For this reason, the survey in Study 2 is only representative of the addressable audience of accessible text tools but not representative of all people with cognitive impairments.

Another limitation is that our investigation focused on German. While many of the insights are likely to be applicable to other languages, especially other Germanic languages like English, further research is needed to confirm this. We also found that many deep learning approaches are unavailable even for a comparatively widely spoken language like German. Additional research is needed to address this gap.

7 CONCLUSION

Considering the many people who struggle with reading, better tools are needed to make text more accessible. We identified relevant stakeholders and scenarios and provided a framework to shape what accessible text tools can and should look like. Based on a combination of expert interviews and surveys, we describe in which scenarios such tools are especially useful (RQ1) and who could benefit from accessible text tools (RQ2). We also provide an overview of different accessible text tools useful to stakeholders (RQ3) and discuss what the interface of such tools should look like (RQ4). Based on our empirical findings, we propose the Accessible Text Framework as a way to highlight the tension between information that needs to be compressed, e.g., by summarizing information and by reducing reading volume, and information that needs to be expanded, e.g., by providing explanations and by improving the structure and flow of a text. The framework also presents a socio-technical solution to the problem of balancing these two extremes, e.g., by putting stakeholders in the loop and personalizing the experience. The findings from our mixed-methods investigation allow us to formulate clear recommendations on what research on accessible text tools is needed. We believe that the insights provided in this paper can empower researchers, activists, and civic hackers to design and develop tools that make text more accessible, thus helping the millions of people who struggle with reading.

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