



## OPEN ACCESS

## EDITED BY

Hendrike Frieg,  
University of Applied Sciences and Arts  
Hildesheim, Germany

## REVIEWED BY

Bryan Abendschein,  
Western Michigan University, United States  
Barbara Schneider,  
Osnabrück University of Applied Sciences,  
Germany

## \*CORRESPONDENCE

Naizeth Núñez Macías  
✉ naizeth23@ru.is  
Martina Hielscher-Fastabend  
✉ martina.hielscher@uni-bielefeld.de  
Hendrik Buschmeier  
✉ hbuschme@uni-bielefeld.de

## †PRESENT ADDRESS

Naizeth Núñez Macías,  
Department of Computer Science, Reykjavik  
University, Reykjavik, Iceland

RECEIVED 28 February 2023

ACCEPTED 09 May 2023

PUBLISHED 20 June 2023

## CITATION

Núñez Macías N, Hielscher-Fastabend M and  
Buschmeier H (2023) Use and acceptance of  
voice assistants among people with aphasia in  
Germany. *Front. Commun.* 8:1176475.  
doi: 10.3389/fcomm.2023.1176475

## COPYRIGHT

© 2023 Núñez Macías, Hielscher-Fastabend  
and Buschmeier. This is an open-access article  
distributed under the terms of the [Creative  
Commons Attribution License \(CC BY\)](#). The use,  
distribution or reproduction in other forums is  
permitted, provided the original author(s) and  
the copyright owner(s) are credited and that  
the original publication in this journal is cited, in  
accordance with accepted academic practice.  
No use, distribution or reproduction is  
permitted which does not comply with these  
terms.

# Use and acceptance of voice assistants among people with aphasia in Germany

Naizeth Núñez Macías\*†, Martina Hielscher-Fastabend\* and  
Hendrik Buschmeier\*

Faculty of Linguistics and Literary Studies, Bielefeld University, Bielefeld, Germany

Aphasia is an acquired disorder that affects the ability to communicate. The increasing availability of voice assistants (such as Amazon Alexa or Google Assistant) provides new opportunities to support people with aphasia in a variety of tasks, from everyday communication to speech and language therapy exercises. To ensure accessibility and acceptance, it is important to involve people with aphasia in the development process. Using the Unified Theory of Acceptance and Use of Technology (UTAUT2) as a theoretical framework, this study examines their willingness to use voice assistants and explores which potential applications they consider useful for participation in social and cultural contexts. These questions were addressed through a survey. Eight people with aphasia took part in the study. Although the sample size does not allow for statistical analysis, the results provide valuable insights for further research. Most of the participants showed a general interest in using voice assistants, two of them were already users. The presence of physical limitations motivates the use of speech-based technology. Participants who already used voice assistants saw them as a practical support in everyday life, while non-users had lower expectations in this respect. Social influence was found to play an important role. Participants' perceptions of privacy and data security issues varied and do not allow for generalization. Finally, some participants showed a preference for communication support applications (e.g., word finding, sentence formation, grammar support) over applications used for therapy exercises such as word training.

## KEYWORDS

voice assistants, aphasia, speech and language impairments, assistive technologies, technology acceptance

## 1. Introduction

Aphasia is an acquired language disorder caused by brain damage that can affect all language modalities (listening, speaking, reading, and writing) to varying degrees, depending on the location and extent of the brain damage. Symptoms of aphasia can manifest themselves at all levels of language, from phonology to difficulties in word formation, vocabulary and semantic problems, as well as syntactic and pragmatic abnormalities (Clark and Cummings, 2003; Damico et al., 2021; Schneider et al., 2021). A common symptom is word finding difficulties, which may manifest as semantic or phonemic paraphasias or tip of the tongue phenomena. Accompanying symptoms may include motor deficits and cognitive impairments such as deficits in attention, short-term and working memory, and executive functions (memory, action planning, problem-solving thinking; Thöne-Otto, 2017; Code, 2021).

Aphasia affects more than 100,000 people in Germany. In 80% of the cases, the brain damage is caused by a stroke due to an ischemic or hemorrhagic insult. The remaining causes include acquired brain injury, brain tumors, inflammatory diseases, hypoxia (lack of oxygen), and brain atrophy (Bundesverband Aphasie e.V., 2022). As stroke is the most common cause of aphasia and strokes affect people over the age of 55 (Sudlow and Warlow, 1997), aphasic patients are often middle-aged or elderly. Aphasia is often accompanied by negative emotional and psychosocial changes. Social participation, carrying out activities of daily living and returning to work become more difficult, resulting in the need for support in several areas of life and a change in roles within families (Nätterlund, 2010; Beals et al., 2016; Code, 2021; Schneider et al., 2021).

The variety of symptoms experienced by people with aphasia also makes it difficult to interact with products and technologies such as mobile phones, creating a barrier to digital participation (Greig et al., 2008; Brandenburg et al., 2013). A study of the digital divide among people with disabilities (Johansson et al., 2021) found that a higher percentage of people with aphasia reported difficulties with finding information, navigating, understanding information, and using passwords compared to people with autism, attention deficit hyperactivity disorder (ADHD) and bipolar disorder. In addition, women with aphasia reported feeling more digitally excluded than other disability groups, including people with visual and fine motor impairments. However, the study by Johansson et al. (2021) focused on technology controlled by touch screens or keyboards. To our knowledge, there are currently no studies on the attitudes and barriers that people with aphasia face when interacting with voice assistants, which are digital assistants that are primarily voice controlled.

A particularity of voice assistants is that they offer the possibility of a human-computer interaction that is more similar to human-to-human interactions, compared to graphical user interfaces (Yaghoubzadeh et al., 2015; Nasirian et al., 2017). Olafsson et al. (2021) found that even though traditional tap and swipe user interfaces are often preferred over conversational interfaces for tasks under time pressure and for quick transactional tasks, conversational agents are an alternative for older users and users with lower computer and smartphone literacy.

Due to the growing popularity of voice assistants and their low cost (compared to other technologies such as robots), it is necessary to focus scientific attention on such products and their potential as assistive technologies (Masina et al., 2020). Functions such as reminders (Hellwig et al., 2018; Malapaschas, 2021), Smart Home applications, infotainment, communication (calls and messages; Hellwig et al., 2018), health documentation (Hellwig et al., 2018; Zhang et al., 2023), and managing shopping, to-do lists (Pradhan et al., 2018), or structuring the day (Kopp et al., 2018) can optimize the quality of life of people with physical, cognitive, and language or speech impairments and give them a sense of independence. At the same time, the workload of caregivers and medical staff can be reduced (Hellwig et al., 2018; Zhang et al., 2023).

The most popular commercial voice assistants are Amazon Alexa, Apple Siri, and Google Assistant. Amazon and Google offer a variety of dedicated hardware devices (often called smart speakers) for their voice assistants. However, many other devices that can

connect to the Internet provide additional hardware for interaction, such as smartphones, smart TVs, or tablet PCs (Hoy, 2018). Since their introduction, voice assistants have become increasingly popular, as evidenced by the growing number of users. According to a survey conducted in May 2020, two out of five internet users in Germany (39%) use voice commands (Paulsen and Klöß, 2020). One year later, 44% of Internet users were already using voice applications (Klöß, 2021).

Commercial voice assistants are considered web interfaces, meaning that users can use such systems to access information through search engines, as well as to access services and resources such as email, phone calls, and messages (Natale and Cooke, 2021). Researchers have identified music, search, and smart home devices (e.g., smart lights, thermostats) as the most commonly used command categories (Ammari et al., 2019). Other functions recognized as potential uses of mobile technologies to enhance participation of people with aphasia (Brandenburg et al., 2013) can be fulfilled by voice assistants, e.g., supporting interpersonal relationships through chatting and social networking, and enabling activities such as online shopping, managing, and remembering tasks and schedules, or video calling. The publication of the World Health Organization's International Classification of Functioning, Disability, and Health (ICF; World Health Organization, 2001) has resulted in an international interest in "participation" as the most important factor for rehabilitative outcomes. The ICF defines participation as involvement in a life situation and participation restriction is defined as problems an individual may experience in involvement in life situations. In the context of language problems and aphasia a regain of participation means the regain of communicative opportunities and the enhancement of chances to take part in individual private, social and cultural discourse. Of course, there is no universal definition and operationalization of the concept of verbal or communicative participation in people with aphasia, but Schneider et al. (2021) try to outline factors for diagnostic issues and therapeutic approaches.

Voice assistants such as Alexa and Google Assistant provide access to their application programming interfaces (APIs), opening up the possibility of developing custom applications (Hoy, 2018; Coates, 2019; Walls, 2022). This allows developers to create new features to address the unique needs of people with speech and language impairments. Here, we focus on applications for people with aphasia.

International organizations and researchers recognize the usefulness of digital assistants for people with aphasia. The National Aphasia Association in the United States recommends the use of commercial voice assistants, highlighting the advantage that such systems never tire (National Aphasia Association, 2022). Beals et al. (2016) highlight that technology offers the advantage of never getting bored and potentially reducing feelings of shame about the language disorder. In Europe, The Tavistock Trust For Aphasia, a UK-based organization, also recommends the use of voice assistants and lists use cases such as practicing everyday phrases and simple conversations (Aphasia Software Finder, 2022). It also publishes a list of Amazon Alexa skills, available in English, that people with aphasia can benefit from.

Qiu and Abdullah (2021) give a very visionary positive sight on the potentials of voice assistants to assist people with language

problems. Further research has explored the suitability of voice assistants in speech and language therapy for children with autism using a prototype application (an Amazon Alexa skill) that would deliver images through an iPad (Allen et al., 2018) or directly through an Amazon Echo Show (an Alexa-enabled device with display; Yu et al., 2018). Allen et al. (2018) found that the accuracy of the speech recognition was insufficient for use in a clinical setting. However, when the speech recognition succeeded and the images were successfully retrieved, the participants (children with autism) consistently followed the target directive. The study of Yu et al. (2018) reported a higher accuracy in retrieving visual content and an overall positive response by the participants (speech and language therapists). Hricová and Glady (2023) explored advantages and disadvantages of using voice assistants for speech and language therapy with children. Additionally, the authors present a list of publicly available Amazon Alexa skills and describe the therapy goals that these skills can support. Other researchers have examined the accessibility and potential uses of voice assistants with target groups such as people with cognitive (Masina et al., 2020; Malapaschas, 2021), motor, or language limitations (Masina et al., 2020). These studies suggest that voice assistants can be used as an assistive technology and increase participation in everyday life. The role of the family members in the rehabilitation process and as main supporters in choosing and learning how to use assistive technologies is emphasized in both studies. Equally relevant to this topic are studies about other implementations of speech technologies in the context of speech and language impairments. Beals et al. (2016) analyzed the components of speech technologies in terms of applicability to language disorders such as aphasia and language development disorders such as dyslexia or autism spectrum disorders. Researchers have also studied the suitability of robots in speech therapy (Malchus et al., 2013, 2019). It was found that speech therapists would be willing to use social robots in aphasia therapy if they had certain characteristics such as adaptability and very good language production and comprehension capabilities (Malchus et al., 2013).

However, people with speech and language impairments are often not understood by commercially available voice assistants because they have been trained on audio recordings of healthy speakers. As a result, variations in breathing, phonation, and articulation lead to lower speech recognition performance (Beals et al., 2016). Despite lower performance, Pradhan et al. (2018) found that people with speech and language impairments are using voice assistants. Their analysis of reviews of the Amazon Alexa Echo Show device showed that family members of people with speech and language impairments perceived an improvement from interacting with voice assistants. Opinion articles emphasize that people with speech and language disorders can benefit enormously from the use of speech technology, e.g., by providing a higher degree of participation and independence (Corcoran, 2018) or by making speech therapy more accessible (Kevin Wheeler, 2020), and criticize that this target group has not been taken into account in the design of the technology. Therefore, it is claimed that the data for training speech recognition should be improved. Perhaps as a result of such criticism, manufacturers of voice assistants are making efforts to improve speech recognition for people with language

TABLE 1 Extended UTAUT2 according to Kessler and Martin (2017).

Determinants	Meaning
Performance expectancy	"The degree to which using a technology will provide benefits to consumers in performing certain activities" (Venkatesh et al., 2012, p. 159)
Effort expectancy	"The degree of ease associated with consumer's use of technology" (Venkatesh et al., 2012, p. 159)
Social influence	"Is the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology" (Venkatesh et al., 2012, p. 159)
Facilitating conditions	"Consumers' perceptions of the resources and support available to perform a behavior" (Venkatesh et al., 2012, p. 159)
Price value	"When the benefits of using a technology are perceived to be greater than the monetary cost" (Venkatesh et al., 2012, p. 161)
Habit	"The extent to which people tend to perform behaviors automatically because of learning" (Venkatesh et al., 2012, p. 161)
Data security	"Showing transparency and control over the gathered information" (Kessler and Martin, 2017, p. 17)
Connectivity	"When a user wants his purchased technology to be connected to others for interaction reasons" (Kessler and Martin, 2017, p. 18)
Relationship with the device	"The effects of the relationship between intelligent machines and human beings" (Kessler and Martin, 2017, p. 18)

impairments (Cattiau, 2019; Deighton, 2021; MacTechNews.de, 2022).

Previous research has analyzed the acceptance factors influencing the adoption of digital assistants by older people (Koon et al., 2020), but to our knowledge there is no research on the acceptance of such systems by people with aphasia. By evaluating acceptance, it is possible to identify requirements and needs, the fulfillment of which can enable people with aphasia to benefit from such systems. Here, the Theory of Acceptance and Use of Technology 2 (UTAUT2; Venkatesh et al., 2012) in the version adapted by Kessler and Martin (2017) was chosen for the analysis of acceptance factors because of its focus on artificial intelligence technology. This model considers the following factors: Performance expectation, effort expectation, social influence, facilitating conditions, price value, habit, data security, connectivity, and relationship with the device (Kessler and Martin, 2017). The definitions of the determinants are summarized in Table 1.

The purpose of this study is to examine the desirability of using commercial speech assistants as a communication aid and adjunct to speech therapy for people with aphasia. In order to verify the suitability of voice assistants, this study examines the factors that influence the adoption of voice assistants by people with aphasia. In addition, our study addresses the question of which use cases people with aphasia find useful for better participation in social life. The present work is intended to serve as a basis for the future development of applications for voice assistants that support people

with aphasia and aims to contribute to closing the research gap in this area.

## 2. Materials and methods

We conducted a survey<sup>1</sup> to find out about the willingness of people with aphasia in Germany to use commercially available voice assistants in their everyday life and in speech and language therapy, as well as the factors that influence the adoption of voice assistants. An online questionnaire was created using the EFS Survey Software Unipark. The study was reviewed and approved by the internal ethics committee of Bielefeld University (reference no. 2021-222).

For data collection, the link to the online questionnaire was sent to self-help groups through the Stiftung Deutsche Schlaganfall-Hilfe and placed on the web page of the Aphasia 4.2 Online Congress in Germany. In addition, cooperation partners of the researchers were asked to forward the online questionnaire to their patients with aphasia. The survey was made available between March and June 2022. One participant completed the questionnaire during a telephone conversation with one of the researchers. Two additional participants completed a paper version of the questionnaire in October 2022. Participants were made aware of the voluntary nature of their participation and informed that their data would be handled in accordance with data protection regulations. Data collection was anonymous and no compensation was offered.

### 2.1. Participants

The target group of the study was people with aphasia, regardless of whether or not they were using voice assistants at the time of the study. A total of eight people with aphasia (three males: A1–A3 and five females: A4–A8) participated in the study. Age was reported in age groups: 36–50 years (A1, A4, A5, A6), 51–65 years (A2, A3), and 66–80 years (A7, A8). A2 did not complete the survey, but their available responses are analyzed in this study (as this was an online questionnaire, the reason for the interruption is unknown to the authors).

### 2.2. Questionnaire

The questionnaire contained between 49 and 53 questions. In addition to demographic data, the survey included a 5-point Likert scale (strongly agree to strongly disagree) rating of potential applications to support people with aphasia. Participants were asked about their experience with voice assistants and with technology in general. Participants who had used voice assistants answered questions about how they used the assistant, while participants who had not used voice assistants were asked about their reasons for not using them. These questions were related to the acceptance factors of the UTAUT2 model. An overview of the assignment of the questions to the UTAUT2 model can be found in Table 2. Most of the questions used a 5-point Likert scale (strongly

TABLE 2 Summarized overview of the questions and their assigned determinants according to the UTAUT2 model by Kessler and Martin (2017).

Determinant	Questions
Performance expectancy	—Motivation for using voice assistants (open question) —The voice assistant generally understands me well —I am afraid of not being understood by the voice assistant —The voice assistant is/would be a good support in everyday life —The voice assistant is/would be a motivation to improve my language
Effort expectancy	—Using the voice assistant is easy for me —I don't know how voice assistant work —I need help in dealing with technology —I am interested in technologies —I often have to ask how my computer/tablet/smartphone works
Social influence	—I have family and/or friends who support me in dealing with technology (yes/no) —Use by friends or relatives (yes/no) —Recommendation by friends or relatives (yes/no)
Facilitating conditions	—Access to internet (yes/no) —Access to internet-enabled devices (multiple choice) —Using computers and cell phones is complicated due to physical limitations —I can imagine using voice assistants at home in the future
Price value	—Buying a voice assistant is too expensive for me
Habit	—Frequency of use (multiple choice) —Used functions (multiple choice)
Data security	—I am concerned about the security of my data
Connectivity	—On what device is the voice assistant being used, e.g. smart speakers, smartphone, etc. (multiple choice)
Relationship with the device	—I get frustrated when the voice assistant doesn't understand me well —I think it is amusing/weird to talk to a machine

agree to strongly disagree). Questions with a different format are specified in Table 2. The original questionnaires are available in the Supplementary material.

## 3. Results

Aphasia has been present for more than a year in almost all cases, only in A7 it was present for less than six months. Two participants (A4, A5) reported using voice assistants at the time of the survey. All participants reported having an internet connection and at least one internet-enabled device at home: Computer or laptop ( $n = 8$ ), smartphone ( $n = 7$ , except for A1), tablet or iPad ( $n = 3$ ), or smart TV ( $n = 2$ ). None of the participants used

<sup>1</sup> Most of the participants answered the survey online due to COVID-19 restrictions that made it difficult to meet participants in person.

TABLE 3 Individual participants' (A1, A3–A8) evaluation of voice assistant applications for supporting people with aphasia.

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I would like to integrate voice assistants into the speech therapy I am currently doing	A4, A5, A6	A8		A1, A7	A3
Exercises with voice assistants should be used as homework in my speech therapy	A4, A5, A6	A8		A1	A3, A7
I would like to be able to ask the voice assistant for help when I cannot remember a word	A3, A4, A5, A6, A8		A7	A1	
I would like to train words with the voice assistant	A3, A4, A5, A8		A6	A1, A7	
I would like to get help with grammar from the voice assistant	A3, A4, A5, A6, A8		A7		A1
I would like to ask the voice assistant how to form a sentence	A3, A4, A5, A6, A8			A7	A1
In my opinion, a voice assistant can replace my speech therapy	A1, A4, A5		A6, A8		A3, A7

A2 did not answer these questions.

voice assistants prior to their aphasia, and only A4 and A7 reported having used a therapy app.

In this section, we present the results of the survey in two parts. In Section 3.1, we summarize the evaluation of a list of potential applications to support people with aphasia in everyday communication and during speech and language therapy. Section 3.2 is dedicated to analyzing the factors that either encourage or discourage individuals with aphasia from utilizing voice assistants. We sum up the feedback provided by both voice assistant users and non-users separately.

We analyzed the data as follows: Questionnaire responses from all participants were collected in a spreadsheet. The responses were then compiled into tables, such as Table 3, from which the acceptance factor analysis was performed. In the following description of the results, participants were grouped based on their responses (e.g., to the questions in Table 2), thus identifying profiles and individual attitudes, preferences, or usage patterns. The data is available in the Supplementary material.

### 3.1. Potential applications for people with aphasia

Participants were asked to rate, on a 5-point Likert scale, potential use scenarios for voice assistants to support people with aphasia. These features are not currently available, but it is possible to develop such applications. The results are summarized in Table 3. There are notable differences between participants who have used voice assistants and those who have not. A4 and A5 rated all of the proposed applications positively, whereas the opinions of the participants who did not use voice assistants ranged from very positive to very negative. In addition, some participants showed more interest in using applications to help with grammar, sentence formulation, or word finding difficulties than in speech therapy applications such as word training or doing exercises assigned by the therapist. An unexpected finding was that three participants agreed to the statement that their therapy could be replaced by

voice assistants. However, the authors see the use of voice assistants mainly as a resource for better access to information and for participation in daily routines.

## 3.2. Perception of voice assistants

In this section, we analyze the factors that influence or inhibit the use of voice assistants by people with aphasia. For clarity, responses from users and non-users of voice assistants are discussed separately.

### 3.2.1. Users

Two participants reported using voice assistants several times a day on a smart speaker and a smartphone (A4 and A5). A4 also reported using the voice assistant on a tablet or iPad and on a computer. Both participants use Google Assistant and Amazon Alexa. A4 also uses Bixby (a voice assistant by Samsung).

When asked what motivated them to use a voice assistant, they refer to existing deficits (e.g., A4: *“richtig schreiben, fehlerlos, ist mit Aphasie nicht mehr möglich”* [“writing correctly, without errors, is no longer possible with aphasia”]) and to feelings of shame that do not arise during interaction with the voice assistant, possibly in contrast to interaction with other people (A5: *“um Hilfe zu finden”* [“to find help”], *“die Antworten die man bekommt ohne als dumm zu wirken”* [“the answers you get without being perceived as dumb”]). Positive aspects of the voice assistant are that users do not have to write (A4) and that the information they receive from the assistant is polite and accurate (A5). As a negative aspect, A5 reported that the voice assistant speaks too fast and sometimes cannot understand the commands.

A4 and A5 have in common that they perceive the voice assistant as a good support in everyday life, but they are neutral about the voice assistant as a motivation to improve their language. Further results show that A4 and A5 have fundamentally different perceptions of their experience with voice assistants. A5 reported finding the voice assistant easy to use and being well understood

by it. A4 was neutral about the ease of using voice assistants and being sometimes misunderstood by them. There is also a wide variation in their assessment of their technology competence and the frequency with which they ask for help when using mobile devices such as computers, tablets, or smartphones. A4 reported high confidence in using technology and rejected the need to constantly ask for help, while A5 was neutral about her technological competence and reported a constant need for help in using mobile devices.

A4 and A5 are unique in that they both have someone in their environment (family or friends) who has already used a voice assistant and recommended it to them, as well as someone who supports them in using technology. In addition, both participants indicated that physical limitations make it difficult for them to use mobile devices. However, further information about these limitations was not available to the researchers.

Both participants use the following functions: timer, calls, writing messages, listening to the radio, asking about the weather and asking for addresses. A4 also uses features such as online shopping and shopping lists, and smart home features such as turning lights on and off and controlling the TV. A5 also listens to online books and asks for jokes.

Concerns about data security are partially present for A5, but not for A4.

A4 reported that she was sometimes misunderstood by the voice assistant and felt frustrated when this happened. She also rejected finding it amusing to talk to a machine. On the other hand, A5 is not frustrated with the device due to lack of understanding and is partially comfortable talking to a machine.

### 3.2.2. Non-users

When asked which voice assistants they had heard of, all non-users except for A3 reported knowing Amazon Alexa and Google Assistant. Other known voice assistants are Microsoft Cortana ( $n = 2$ ), Apple Siri ( $n = 1$ ) and Magenta ( $n = 1$ ).

Participants were presented a list of possible reasons for not using voice assistants and were asked to evaluate the statements on a 5-point Likert scale. A8 reported having difficulties answering these questions and left them unanswered. Instead, she expressed verbally that she did not use voice assistants because it was all too new for her. Two of the non-users (A1, A6) reported that they feared to be misunderstood, for A2, A3 and A7 this was not the case. Non-users showed some skepticism regarding the potential of voice assistants to support them in their everyday life. Only A8 evaluated this statement positively, A6 and A7 were neutral about it and A1 and A3 rejected it. A6 and A8 indicated that voice assistants could be a motivation to improve their language, while A7 was neutral about it and A1 and A3 rejected this statement. A further reason for not using voice assistants was the lack of knowledge about their functionality. Only A7 reported this not being a relevant factor. A3, A6, and A8 showed interest to use voice assistants at home in the future. The rest of the participants rejected this statement (A1, A7) or left the question unanswered (A2).

Similar to the users, the assessment of their technology competence and the frequency with which they asked for help

when using mobile devices such as computer, tablet or smartphone was highly variable among participants. A1 and A8 reported being interested in new technologies and being able to handle them well without the need of asking for help. A3 was neutral about the interest and indicated a low competence and a need for help. A6 indicated a high interest in technology, was neutral about her competence and reported needing help with mobile devices. A7 reported a low interest, was neutral about her competence but indicated not needing help in dealing with mobile devices. Only A8 reported having physical limitations that make the use of mobile technologies complicated. All participants except for A1 reported having someone in their environment that supports them in dealing with technology. Of all the non-users, only A7 had family or friends who used voice assistants. However, they had not recommended using them.

Regarding costs, four participants reported voice assistants being too expensive for them. It can be inferred that the participants did not know about or did not consider the possibility of using voice assistants through devices they already own, e.g., smartphones and computers. Other reasons, such as the concerns about data security and the feeling toward the idea of talking to a machine are rated differently by the participants. A1 and A2 reported having concerns about data security, whereas A3 and A7 were neutral about it and A6 rejected having such concerns. A1 and A2 affirmed finding it weird to talk to a machine, whereas A3, A6, and A7 rejected this statement. Only A8 found the idea of talking to a machine amusing.

Since it was expected that non-users were not informed about the functionalities of voice assistants, they were given a list of functions and were asked to mark the ones that they would like to use. A total of five participants answered this part of the questionnaire. Non-users reported willingness to use following functions: timer ( $n = 3$ ), reminder ( $n = 4$ ), call ( $n = 1$ ), listening to the radio ( $n = 3$ ), listening to audio books ( $n = 2$ ), controlling TV ( $n = 1$ ), controlling lights ( $n = 2$ ), asking for the weather ( $n = 2$ ), asking for addresses ( $n = 3$ ), texting ( $n = 2$ ), and asking for jokes ( $n = 2$ ).

## 4. Discussion

Research on the use of voice assistants for and by people with speech and language disorders is a promising research area. However, the needs and barriers that may hamper the use of voice assistants by people with different speech and language impairments should be researched separately. In this study, we aim to contribute to the knowledge on the potential uses of voice assistants for people with aphasia. We explored users' perception on the interaction with voice assistants and on functions that could be developed to support this target group, along with expectations and factors that act as inhibitors in the acquisition and use of voice assistants, taking the adapted UTAUT2 model (Kessler and Martin, 2017) as theoretical framework. The rather low number of participants does not allow for a statistical evaluation, nevertheless, the data provides insights that can be used as a reference for future research.

## 4.1. Voice assistants as communication aids and speech therapy tools

Participants were given a list of applications that could be developed for commercially available voice assistants (such as Amazon Alexa and Google Assistant) to support them in their daily life and as complementary tools for speech and language therapy. We posed the additional question if participants believed voice assistants could replace speech therapy in order to identify the attitude toward the idea of voice assistants as replacement vs. as complement of traditional therapy. Regarding the suggested applications, we found that some participants preferred applications for communication support (word-finding, sentence formation, help with grammar) over applications for use in therapy sessions, as homework or self-training. It should be noted though that only two participants had prior experience with other therapy apps, which leads to the possibility that a rejection of using the voice assistant as a tool for therapy is related to a lack of knowledge about the technological possibilities or to a preference of traditional therapy methods. Additionally, we found that the participants who were already users of voice assistants evaluated all the proposed applications positively, while the assessment of non-users ranked from very positive to very negative. This suggests a higher expectancy of useful participation opportunities by users than non-users based on positive experiences with the technology.

People with aphasia and their relatives saw chances for voice assistants to support conversation and thereby strengthen their participative opportunities in several different ways. As pointed out, some participants see additional therapeutic potential in the training situation with their voice assistant, for instance to find the correct words for things they want to address. In addition, voice assistants may help to train the verbal communicative competences of people with aphasia in every-day situations at home. In addition, if further systems can guaranty safe personalized online conversation voice assistants, this may help to get access and support the communication in online formats, which has been shown to be very promising for people with aphasia who have problems with face-to-face conversation, especially in group settings (Cruice et al., 2021). In accordance with Qiu and Abdullah (2021), a positive view on the potentials of voice assistants was found in the answers of even some people with aphasia.

Three out of seven participants (A1, A4, and A5) considered the replacement of speech and language therapy through interaction with a voice assistant as a possible alternative. Nevertheless, the results suggest that the reasoning behind this evaluation may vary. A4 and A5 (both women, 36–50 years old) were users of voice assistants and evaluated all proposed use cases positively, whereas A1 (male, 36–50) did not use voice assistants and rejected being interested in the proposed applications. It should be noted that A1 showed no interest in using voice assistants in the future and did not own a smartphone, which could be interpreted as a general cautiousness toward the use of AI-based technology. Therefore, it is likely that A1 saw the replacement of traditional therapy through voice assistants as possible, though in a negative way. On the other hand, the positive experience of A4 and A5 with voice

assistants may have led to a higher trust in the capabilities of voice assistants, and therefore to the belief that such devices could be able to replace traditional speech and language therapy. However, further research is needed in order to obtain a better understanding of this topic.

## 4.2. Acceptance factors

### 4.2.1. Performance expectancy

We found that people with aphasia who already used voice assistants perceived them as a good support in everyday life, while people with aphasia without experience with voice assistants had low expectations in this regard. Users indicated that difficulties with writing and the possibility of asking for help without feeling ashamed were a motivation for using voice assistants. From these results it can be inferred that users see the potential to cover a need in voice assistants that is not covered by other technological devices or that cannot be covered by the environment (e.g., to avoid family members being overloaded). Nevertheless, users see the voice assistant only partly as a motivation to improve their language, whereas non-users showed very different opinions. For that reason, it cannot be concluded that voice assistants represent a motivational factor.

The fear of not being understood was also rated very differently among non-users, from fear being an important to being an irrelevant factor. Unexpectedly, when relatives of people with aphasia were asked about their own reasons not to use voice assistants, some of them also reported being afraid of not being understood (Núñez Macías, 2022). Therefore, it can be concluded that a negative perception of the accuracy of speech recognition can negatively influence the acceptance and purchase of voice assistants, independent from the presence of language impairments. This fear translates directly to a low performance expectation, since users cannot benefit from the voice assistant if the latter does not understand the user's requests.

In accordance with Beals et al. (2016), the reduction of feelings of shame about the language disorder were also identified in the study. One of the participants reported that a motivation for using voice assistants was the possibility to ask questions without being perceived as unintelligent. This may also suggest a high potential of voice assistants as an assistive technology, since people with aphasia can make use of such system in spite and not because of the language impairment, which makes the technology less stigmatizing than other assistive technologies (Masina et al., 2020).

### 4.2.2. Effort expectancy

The participants who were already users of voice assistants reported different perceptions toward the difficulty of use. One of them perceived it as easy while the other was neutral about it. Yet both perceived the voice assistant as a good support in everyday life. It is therefore possible that users may show a high acceptance of voice assistants in spite of facing difficulties with speech recognition, as long as the technology still offers an advantage over other technologies. In this case, the second user

reported having difficulties writing, resulting in a greater reliance on speech-based technology.

A lack of knowledge about the functionality of voice assistants was often given as a reason for not using them. One of the participants indicated not using them because it was all “too new” for her. This lack of knowledge is expected to be related to the perceived difficulty of use. Following Koon et al. (2020), this indicates that people should be informed about the existence of such technologies and accompanied in the process of adoption and learning.

Questions about the general interest in technology and the need for assistance in using technology were asked to examine to what extent the willingness or refusal to use voice assistants is related to the willingness or refusal to use technology in general. The assessment of their own technology competence and the frequency with which they ask for help was highly variable among participants. It was found that a general interest in technologies or a high self-assessment of technology affinity usually went hand in hand with a higher openness to voice assistants. Nevertheless, one participant reported being highly interested in new technologies but was not willing to use voice assistants in the future. The same participant also reported having concerns about data security and not owning a smartphone. From these results, it can be interpreted that concerns about data security play an important role in that decision. This factor will be further discussed below.

#### 4.2.3. Social influence

Social influence has been found to play an important role in the adoption of voice assistants. The participants who already used voice assistants also had family or acquaintances who used them and who recommended using them. In addition to that, users knew someone in their environment that was able to provide help in dealing with technology, while this was not always the case with non-users. One of the non-users reported knowing people who used voice assistants, however, they had not recommended the person with aphasia to do so. Further research is necessary to explore whether participants purchased the voice assistant by their own or if it was a gift from someone in their environment and what impact this has in continuing the use (Koon et al., 2020).

#### 4.2.4. Facilitating conditions

All participants had access to internet and to internet-enabled devices, yet only two out of eight participants were using voice assistants at the time of the survey. Since most of the answers were gathered via an online-survey, we were unable to reach out to participants who did not have access to such devices, which would have given us some information about the perceptions of people with aphasia who either have no access to the internet, do not feel able to use internet-enabled devices or decided against using them.

The existence of physical limitations that make it difficult to use keyboards or touchscreen displays seems to increase openness to voice-based control and thus to voice assistants, which emphasizes the potential of voice assistants as an assistive technology. Both participants who were users of voice assistants reported having

difficulties in dealing with mobile technologies due to physical limitations. Similarly, one of the non-users reported having such difficulties and being interested in using voice assistants in the future. This factor is considered a facilitating condition in this study because we consider being able to use the voice for device control a resource that is not available in tap-and-swipe user interfaces.

#### 4.2.5. Price value

In spite of the possibility of using voice assistants on several internet-enabled devices, it was found that most non-user participants considered the price of voice assistants as a reason for not using them. Nevertheless, we did not gather information regarding the knowledge about the price of smart speakers. One of the participants who answered the questionnaire on paper reported the price not being a factor only after hearing the price range from the researcher. These results may suggest that not the actual price but the expectation about the price influenced the decision of the participants not to acquire a smart speaker.

#### 4.2.6. Habit

The participants who were users of voice assistants reported using them several times per day for a variety of functions, which denotes a strong habit. It is also noteworthy mentioning that even participants who indicated not being interested in using voice assistants at home in the future selected several functions when asked which functions they would like to use. In that sense, the question about the habit is closely linked to the knowledge about the functionalities of voice assistants.

#### 4.2.7. Data security

We found that there is little consensus on the issue of data security. Privacy concerns play a very different role among the individual participants. While for some participants these sort of concerns are a reason for not using voice assistants, for other participants these are only partial or non-existent. These results accentuate the need of creating guidelines for the research of voice assistants as assistive technologies and the need to evaluate the prerequisites that should be met when developing such systems. This applies both to the manufacturers of voice assistants as well as app developers.

#### 4.2.8. Connectivity

Users of voice assistants reported using at least two providers through smart speakers and a smartphone. This could indicate that the compatibility of the voice assistant with the devices they already own is an important factor for them. However, we did not gather sufficient information about this factor.

#### 4.2.9. Relationship with the device

We found that experiencing difficulties with speech recognition lead to feeling frustrated toward the voice assistant. However, as mentioned in the discussion of effort expectancy above, occasional

feelings of frustration did not seem to affect the overall acceptance of a voice assistant when it still covered a need that was not covered by other devices. Only one participant was enthusiastic about the idea of talking to a machine, while others found this to be a strange idea or were neutral about it. Notably, even one of the participants who were already using voice assistants several times per day reported feeling weird about it. Additionally, as described in the discussion about the performance expectancy, one participant reported that being able to ask questions without feeling ashamed was a motivation to start using the voice assistants. This result may suggest that a feeling of familiarity can be a facilitator for the acquisition and continued use of voice assistants.

### 4.3. Limitations and future directions

A limitation of the study is the rather low participation rate, which does not allow us to draw statistical conclusions. One reason for this is that we were not able to get in contact with participants because of the COVID-19 restrictions. Therefore, we conducted the survey online for the most part. Another difficulty was that some self-help groups did not forward the online questionnaire to their members, due to two assumptions: (1) there would be no interest in the topic of voice assistants due to members' age, and (2) participation would not be helpful for the study, because members were not using voice assistants, yet. Another possible reason for the low participation rate is that the questionnaire was overwhelming for people with aphasia, particularly given that participants were sitting in front of an internet enabled device without being able to ask the researchers for help. One of the participants who answered the questionnaire on paper with the support of one of the researchers expressed being particularly overwhelmed with a set of questions that used a Likert scale. In this case, the participant skipped these questions and continued answering the questionnaire. We can assume that A2 interrupted the survey because of difficulties answering the questions (in the online version of the questionnaire it was not possible to skip questions). Only one participant contacted the researchers and asked for help in answering the questionnaire, which was provided through a telephone call.

The conducted survey is also limited in that it was not possible to explore the motivation behind the Likert scale evaluations, such as the concerns regarding data security and privacy or the statement that voice assistants could replace speech and language therapy. A deeper analysis of factors that create or harm trust toward digital assistants is needed in order to better understand and be able to address the existing concerns. Additionally, people without access to internet-enabled devices as well as people who are limited in their use of keyboards due to physical or visual impairments could not participate in the study due to the chosen method (online survey). Further research should therefore consider adapting the surveying method to the preferences and abilities of the target group (e.g., giving the participants the opportunity to choose between responding to the

survey online, on paper, or conducting in-person or telephone interviews). We plan to continue this research addressing the forementioned limitations as well as extending it to other languages and cultures.

This study is based on a bigger survey conducted as part of a Master's thesis in which not only people with aphasia but also relatives of people with aphasia participated. The Master's thesis also investigated the requirements posed by people with aphasia to a voice application such as an Amazon Alexa skill that provides support in searching for words. A prototype skill was developed and tested in a small usability study with two participants. To facilitate word finding, the skill asked a set of questions in order to then suggest a word (limited to items found in kitchens, e.g., "kitchen sink," "water glass," as well as food items such as "lemon" or "potato"). It was shown that people with aphasia would prefer an interaction with a maximum of five to six questions from the voice assistant. The supported words should cover as many topics and be as specific as possible, and, optionally, provide visual support (Núñez Macías, 2022). More research is needed to develop applications based on the concrete needs and preferences of the target groups. This should involve a broader number of participants for iterative testing as well as for the collection of ideas and concerns. Furthermore, researchers and developers should include relatives in the development process of voice applications, because relatives play a crucial role in increasing the participation of people with aphasia (Schneider et al., 2021).

### Data availability statement

The original contributions presented in the study are included in the [Supplementary material](#), further inquiries can be directed to the corresponding authors.

### Ethics statement

The studies involving human participants were reviewed and approved by the internal ethics committee, Bielefeld University (reference no. 2021–222). The participants provided their written informed consent to participate in this study.

### Author contributions

NN, HB, and MH-F contributed to the conception and design of the study. NN collected and analyzed the data and wrote the first draft of the manuscript. HB and MH-F supervised and critically revised the manuscript. All authors contributed to manuscript revision, read, and approved the final version of the manuscript.

### Funding

We acknowledge the financial support of the German Research Foundation (DFG) and the Open Access Publication Fund of Bielefeld University for the article processing charge.

## Acknowledgments

This paper is based on the Master's Thesis of NN (Núñez Macías, 2022). We thank the Stiftung Deutsche Schlaganfall-Hilfe, the Zentrum für Aphasie und Schlaganfall Unterfranken, as well as the speech therapists and self-help groups that supported us collecting the data.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

- Allen, A. A., Shane, H. C., and Schlosser, R. W. (2018). The Echo™ as a speaker-independent speech recognition device to support children with autism: an exploratory study. *Adv. Neurodev. Disord.* 2, 69–74. doi: 10.1007/s41252-017-0041-5
- Ammari, T., Kaye, J., Tsai, J. Y., and Bentley, F. (2019). Music, search, and IoT. *ACM Trans. Comput. Hum. Interact.* 26, 1–28. doi: 10.1145/3311956
- Aphasia Software Finder (2022). *Voice Activated Assistance*. Available online at: <https://www.aphasiasoftwarefinder.org/voice-activated-assistance>
- Beals, K., Dahl, D., Fink, R., and Linebarger, M. C. (2016). *Speech and language technology for language disorders* (Berlin; Boston, MA: de Gruyter). doi: 10.1515/9781614516453
- Brandenburg, C., Worrall, L., Rodriguez, A. D., and Copland, D. (2013). Mobile computing technology and aphasia: an integrated review of accessibility and potential uses. *Aphasiology* 27, 444–461. doi: 10.1080/02687038.2013.772293
- Bundesverband Aphasie e.V. (2022). *Aphasie*. Available online at: <https://aphasiker.de/aphasie/>
- Cattiau, J. (2019). *How AI Can Improve Products for People With Impaired Speech*. Google. Available online at: <https://blog.google/outreach-initiatives/accessibility/impaired-speech-recognition/>
- Clark, D. G., and Cummings, J. L. (2003). "Aphasia," in *Neurological Disorders*, ed T. Brandt (Amsterdam; Boston, MA: Academic Press), 265–275. doi: 10.1016/B978-012125831-3/50220-3
- Coates, D. (2019). *Voice Applications for Alexa and Google Assistant*. Shelter Island: Manning.
- Code, C. (2021). "Aphasia," in *The Handbook of Language and Speech Disorders*, eds J. S. Damico, N., Müller, and M. J. Ball (Chichester: Wiley Online Library; John Wiley & Sons Ltd.), 286–310. doi: 10.1002/9781119606987.ch14
- Corcoran, M. (2018). *When Alexa Can't Understand You*. Slate. Available online at: <https://slate.com/technology/2018/10/voice-assistants-alexa-siri-speech-disabilities-recognition.html>
- Cruice, M., Woolf, C., Cauté, A., Monnelly, K., Wilson, S., and Marshall, J. (2021). Preliminary outcomes from a pilot study of personalised online supported conversation for participation intervention for people with aphasia. *Aphasiology* 35, 1293–1317. doi: 10.1080/02687038.2020.1795076
- Damico, J. S., Müller, N., and Ball, M. J. (eds.). (2021). *The Handbook of Language and Speech Disorders, 2nd Edn*. Chichester: John Wiley & Sons. doi: 10.1002/9781119606987
- Deighton, K. (2021). Tech firms train voice assistants to understand atypical speech. *Wall Street J.* Available online at: <https://www.wsj.com/articles/tech-firms-train-voice-assistants-to-understand-atypical-speech-11614186019>
- Greig, C.-A., Harper, R., Hirst, T., Howe, T., and Davidson, B. (2008). Barriers and facilitators to mobile phone use for people with aphasia. *Top. Stroke Rehabil.* 15, 307–324. doi: 10.1310/tsr1504-307
- Hellwig, A., Meister, S., Deiters, W., and Schneider, C. (2018). *Sprachassistenten in der Ambulanten Pflege: Ein Leitfaden für den Einsatz von Voice User Interfaces am Beispiel der Kommerziellen Sprachassistenzsysteme Amazon Echo und Google Home für Senioren und Pflegekräfte*. Zukunft der Pflege-Tagungsband der Clusterkonferenz.
- Hoy, M. B. (2018). Alexa, Siri, Cortana, and more: an introduction to voice assistants. *Med. Ref. Services Q.* 37, 81–88. doi: 10.1080/02763869.2018.1404391
- Hricová, M., and Glady, O. (2023). Alexa Skills in der Sprachtherapie. *Logos. Fachzeitschr. Akad. Sprachther. Logop.* 31, 18–23. Available online at: <https://www.prolog-shop.de/media/pdf/18/8c/5f/IMPULSE-Skills-online1-s1.pdf>
- Johansson, S., Gulliksen, J., and Gustavsson, C. (2021). Disability digital divide: the use of the internet, smartphones, computers and tablets among people with disabilities in Sweden. *Univ. Access Inform. Soc.* 20, 105–120. doi: 10.1007/s10209-020-00714-x
- Kessler, S. K., and Martin, M. (2017). *How do potential users perceive the adoption of new technologies within the field of Artificial Intelligence and Internet-of-Things? - A revision of the UTAUT 2 model using Voice Assistants* (Master thesis). Lund University, Lund, Sweden.
- Kevin Wheeler, U. T. (2020). *For People Who Stutter, the Convenience of Voice Assistant Technology Remains Out of Reach*. USA TODAY. Available online at: <https://techxplore.com/news/2020-01-people-stutter-convenience-voice-technology.html>
- Klöß, S. (2021). *Die Zukunft der Consumer Technology-2021*. Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.
- Koon, L. M., McGlynn, S. A., Blocker, K. A., and Rogers, W. A. (2020). Perceptions of digital assistants from early adopters aged 55+. *Ergon.* 28, 16–23. doi: 10.1177/1064804619842501
- Kopp, S., Brandt, M., Buschmeier, H., Cyra, K., Freigang, F., Krämer, N., et al. (2018). "Conversational assistants for elderly users – the importance of socially cooperative dialogue," in *Proceedings of the AAMAS 2018 Workshop on Intelligent Conversational Agents in Home and Geriatric Care Applications* (Stockholm), 10–17.
- MacTechNews.de (2022). *Siri und der Sprachfehler: Apples Assistent soll Toleranter Werden*. MacTechNews.de.
- Malapaschas, A. (2021). *Voice assistants for people with cognitive impairments due to acquired brain injury* (Ph.D. thesis). University of Glasgow, Glasgow, Scotland.
- Malchus, K., Britta, W., and Jaecks, P. (2019). Roboterunterstütztes Benenntraining bei Aphasie – Eine Einzelfallstudie. *Aphas. Verw. Gebiete.* 45, 14–22.
- Malchus, K., Jaecks, P., Wrede, B., and Stenneken, P. (2013). *Einsatz Sozialer Roboter in der Sprachtherapie?! Erhebung eines Stimmungsbildes von Sprachtherapeuten*. Logos. Die Fachzeitschrift für akademische Sprachtherapie und Logopädie, 2.
- Masina, F., Orso, V., Pluchino, P., Dainese, G., Volpato, S., Nelini, C., et al. (2020). Investigating the accessibility of voice assistants with impaired users: mixed methods study. *J. Med. Intern. Res.* 22:e18431. doi: 10.2196/18431
- Nasirian, F., Ahmadian, M., and Lee, O.-K. (2017). "AI-based voice assistant systems: evaluating from the interaction and trust perspectives," in *Proceedings of the 23rd Americas Conference on Information Systems 2017* (Boston, MA).
- Natale, S., and Cooke, H. (2021). Browsing with Alexa: interrogating the impact of voice assistants as web interfaces. *Media Cult. Soc.* 43, 1000–1016. doi: 10.1177/0163443720983295
- National Aphasia Association (2022). *1 Minute Aphasia Tips: Conversation Partner in Your Pocket*. Available online at: <https://www.aphasia.org/stories/1-minute-aphasia-tips-conversation-partner-in-your-pocket/>

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Supplementary material

Supplementary material, containing the original questionnaires as well as participants answers as data, is available at the following OSF-repository: <https://doi.org/10.17605/OSF.IO/9CFMS>.

- Nätterlund, B. S. (2010). Being a close relative of a person with aphasia. *Scand. J. Occup. Ther.* 17, 18–28. doi: 10.3109/11038120902833218
- Núñez Macías, N. (2022). *Nutzung und Akzeptanz von Sprachassistenten bei Menschen mit einer Aphasie* (Master thesis). Bielefeld University, Bielefeld, Germany.
- Olafsson, S., Parmar, D., Kimani, E., K. O'Leary, T., and Bickmore, T. (2021). 'More like a person than reading text in a machine': characterizing user choice of embodied agents vs. conventional GUIs on smartphones," in *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems, ACM Digital Library*, ed Y. Kitamura (New York, NY: Association for Computing Machinery), 1–6. doi: 10.1145/3411763.3451664
- Paulsen, N., and Klöß, S. (2020). *Beliebte Helfer: Sprachassistenten haben sich durchgesetzt*. Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.
- Pradhan, A., Mehta, K., and Findlater, L. (2018). "Accessibility came by accident": use of voice-controlled intelligent personal assistants by people with disabilities," in *CHI '18: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montréal, QC), 1–13. doi: 10.1145/3173574.3174033
- Qiu, L., and Abdullah, S. (2021). "Voice assistants for speech therapy," in *Adjunct Proceedings of the 2021 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2021 ACM International Symposium on Wearable Computers* (New York, NY), 211–214. doi: 10.1145/3460418.3479336
- Schneider, B., Wehmeyer, M., and Grötzbach, H. (2021). *Aphasie: ICF-orientierte Diagnostik und Therapie, 7th Edn*. Berlin: Springer. doi: 10.1007/978-3-662-62835-5
- Sudlow, C. L., and Warlow, C. P. (1997). Comparable studies of the incidence of stroke and its pathological types: results from an international collaboration. International Stroke Incidence Collaboration. *Stroke* 28, 491–499. doi: 10.1161/01.STR.28.3.491
- Thöne-Otto, A. I. T. (2017). "Nutzung des Internets in der neuropsychologischen Behandlung von Patienten mit Aphasie," in *Neue Technologien in der Sprachtherapie*, eds K. Bilda, J. Mühlhaus, and U. Ritterfeld (Stuttgart: Georg Thieme Verlag), 117–127.
- Venkatesh, V., Thong, J. Y. L., and Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS Q.* 36:157. doi: 10.2307/41410412
- Walls, C. (2022). "Build talking apps: develop voice-first applications for Alexa," in *The Pragmatic Programmers*, ed J. Carter (Raleigh, NC: The Pragmatic Bookshelf).
- World Health Organization (2001). *International Classification of Functioning, Disability and Health: ICF*. Geneva: World Health Organization.
- Yaghoobzadeh, R., Buschmeier, H., and Kopp, S. (2015). "Socially cooperative behavior for artificial companions for elderly and cognitively impaired people," in *Proceedings of the 1st International Symposium on Companion-Technology* (Ulm), 15–19.
- Yu, C., Shane, H., Schlosser, R. W., O'Brien, A., Allen, A., Abramson, J., et al. (2018). An exploratory study of speech-language pathologists using the echo show to deliver visual supports. *Adv. Neurodev. Disord.* 2, 286–292. doi: 10.1007/s41252-018-0075-3
- Zhang, J., Wu, J., Qiu, Y., Song, A., Li, W., Li, X., et al. (2023). Intelligent speech technologies for transcription, disease diagnosis, and medical equipment interactive control in smart hospitals: a review. *Comput. Biol. Med.* 153:106517. doi: 10.1016/j.compbiomed.2022.106517