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A Scoping Review of Literature Using Speech Recognition Technologies by Individuals with Disabilities in Multiple Contexts

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Implications for Rehabilitation

- Speech recognition technology (SRT) provides a method of access that is widely available in mainstream technology devices such as personal computers, smartphones and mobile devices, and smart speakers/daily living aids.
- SRT may improve participation and independence of individuals with disabilities in contexts such as primary and secondary education, post-secondary education, and with independent living tasks.
- Many studies examining SRT are non-empirical, and there is an opportunity for assistive technology professionals and other providers who use assistive technology to continue to develop a rigorous body of knowledge.

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A Scoping Review of Literature Using Speech Recognition Technologies by Individuals with Disabilities in Multiple Contexts

Purpose: Speech recognition technology (SRT) is increasingly available and may provide opportunities for individuals with disabilities to participate in necessary activities and meaningful occupations. This inquiry methodically collects and reports on research related to SRT for individuals with disabilities and impairments.

Materials and Methods: Using the Arksey and O'Malley [1] framework and PRISMA guidelines [2], five databases were queried and indexes of 11 journals were hand-searched for relevant articles. Articles were included if they were published after 2005, involved SRT, written in English, and participants(s) had a disability. Articles were charted, categorized for level of evidence, and findings were summarized.

Results and Conclusions: Of the 78 articles that were retrieved, 13 met inclusion criteria and were organized into 4 categories: SRT in primary and secondary education, in post-secondary education, for daily living, and without a specified context. No included articles considered SRT in vocational contexts. It was determined that SRT is a tool that may improve participation and independence of individuals with disabilities in multiple contexts. Most studies reviewed were non-empirical. Opportunities exist for providers to continue to develop a rigorous body of knowledge for the use of SRT to meet educational, vocational and daily living needs.

Keywords: assistive technology, speech recognition, scoping review, evidence-based practice, school

Introduction

Speech recognition technology (SRT) provides a method of access that is widely available in mainstream technology devices such as personal computers, smartphones and mobile devices, and smart speakers/daily living aids. It is estimated that 46% of American adults use SRT to control their computer, mobile device or media device [3].

These mainstream technologies hold great potential as assistive technologies. This scoping review aims to examine the literature related to speech recognition as an assistive technology, summarize the findings, and identify gaps in the literature.

When an individual with a disability experiences limitations in performing meaningful daily activities, an interdisciplinary team works closely with them and their family/caregivers to determine the best strategies to overcome barriers. Depending on the context, several members of an interprofessional team may participate in making appropriate suggestions. These professionals may include occupational therapists, speech and language pathologists, special educators, teachers for the visually impaired, physical therapists, or others. Solutions may consider adapting the task, using specialized strategies, or incorporating the use of assistive technologies [4].

The World Health Organization's (WHO) International Classification of Functioning, Disability and Health (ICF) defines assistive technology (AT) as "any product, instrument, equipment or technology adapted or specially designed for improving the functioning of a disabled person" [5]. SRT is a method of access that may be a useful assistive technology tool for individuals with disabilities. It can be used for device control or to dictate text in personal computers, perform functions such as initiating voice calls or send text messages on mobile devices, access a growing library of features that includes setting reminders and accessing entertainment on smart speakers, and operate electronic aids to daily living to complete every day activities such as opening doors and operating lighting. These tools may be an accessible method of input for individuals who experience paralysis or other impairments of motor function, as well as provide a compensatory strategy for an author with a language or learning disability [6]. In this scoping review, we seek to determine for individuals with disabilities, if speech recognition technology as compared to conventional device access, is effective for improving access when attempting to achieve educational, vocational and independent living goals.

Methods

A scoping review is a process that seeks to examine the range of research activity and determine the value of performing a full systematic review. Further, a scoping review seeks to summarize and disseminate research findings and identify gaps in the literature on a particular topic. This study followed the steps outlined by the Arksey and O'Malley Framework [1] and the PRISMA guidelines [2].

Search Procedures

The first step was to identify a research question. In this scoping review, we asked, "is speech recognition technology, as compared to conventional device access, effective for improving access and achievement of educational, vocational and independent living goals for individuals with disabilities?'

The second step of a scoping review is a literature review. Studies were identified through 5 databases: CINAHL, ERIC, PubMed, PsychInfo, and Web of Science. The indexes of 11 journals were hand-searched for relevant articles, including the Journal of Technology and Disability, the British Journal of Occupational Therapy, and the American Journal of Occupational Therapy. See table 1 for a complete list of journals hand searched. Searches were carried out using a combination of key terms: "speech recognition" AND "disability", "speech recognition technology" AND "disabilities", "speech recognition" AND "independent living", "speech recognition" AND "disability" AND "education", and "technology AND disability". As recommended by Peters et al., reference lists for more recent articles were also searched for relevant articles [7].

As part of stage 3 of a scoping review, article titles and abstracts were screened for meeting inclusion criteria. Initial inclusion criteria included a publish date after 2000, involved speech recognition technology, were written in English, and subject(s) or participants(s) have a disability as defined by the Americans with Disabilities Act [6]. If the relevance of a study was unclear from the abstract, the full article was retrieved and reviewed. Studies that did not involve speech recognition assistive technology (such as those discussing augmentative and alternative communication (AAC) speech generating devices) and studies not including individuals with disabilities were excluded.

In stage 4, the remaining articles were appraised using a critical appraisal form. Information was extracted and charted by both of the authors for each study. Once articles were charted, the authors categorized the articles using the Joanna Briggs Institute (JBI) Levels of Evidence Scale for Effectiveness [7]. If the article did not meet criteria for levels 1-4, it was excluded. Use of the JBI levels of evidence placed priority on studies whose methods compare SRT to a comparison group, often conventional device access.

Results

The initial search yielded 78 articles. The stage 3 abstract review reduced the number of relevant articles to 33.

During the stage 4 review, the authors chose to exclude articles published before 2005, as SRT has changed greatly in accuracy and reliability since then. A review of published articles from 2000-through 2004 portrayed SRT as a new technology with limitations in accuracy and effectiveness, and did not account for advances in the technology that resulted in reductions in training time, improved accuracy, and enhanced utility. The SRT described in these early articles was not comparable to the current state of this tech. As a result, 20 additional studies were excluded from the scoping review. See figure 1 for a flow diagram on the process of including articles in this review.

Articles included in the review were organized into 4 categories: those that considered SRT in primary and secondary education setting, those that considered SRT in post-secondary education settings, those that considered SRT for daily living activities, and those who considered SRT for computer access without specifying a context. No articles that were included considered SRT in vocational contexts. Figure 1 contains a summary of articles included in this analysis. Table 2 contains a full summary for articles that met inclusion criteria for this scoping review.

SRT in Primary and Secondary Education

Four studies included in the current analysis examined speech recognition in primary and secondary education contexts [9,10,11,12]. One of these studies was considered to be a quasi-experimental design, one an observational-analytical design, one an observational descriptive design, and one an expert opinion/bench research design. Overall, the included studies demonstrated that speech recognition can be helpful for students with disabilities in primary and secondary education contexts. A pre-test/post-test design study examining the use of speech recognition in 5 high school students with physical disabilities found that SRT improved fluency and length of documents as compared to keyboard driven word processing; however, accuracy was lower compared to using keyboard driven word processing [10]. A systematic review of all assistive technologies in primary and secondary settings included 2 studies that examined speech recognition, both of which resulted in a significant improvement in performance [11].

Shadiev et al. conducted a systematic review of descriptive studies on the use and impact of speech recognition in students with cognitive and physical disabilities as well as individuals without disabilities [12]. Their analysis noted that speech recognition has improved and become more reliable over the years, and educators have begun to apply SRT as a universal design for learning tools for taking notes, completing homework assignments and preparing for exams [12]. Gardner conducted a review considering SRT as a tool for students with disabilities in K-12 education. Although SRT decreases the need for writing assistance from teachers, Gardner emphasized that the time necessary to learn SRT and low speech recognition accuracy can be significant barriers to success [9]. Accuracy can especially be an issue for students with dysarthric speech [9]. All authors concluded that more research on the effectiveness of SRT is needed with individuals with different disabilities such as those with speech disorders [9,10,11,12]. Maor et al. highlighted that rapid changes in SRT makes it difficult for researchers to identify the most effective SRT, or establish reliable outcome measures and conduct rigorous study designs [11].

SRT in Post Secondary Education

Four studies included in this analysis considered SRT in the context of post secondary education settings, including undergraduate, graduate and vocational programs. Two of these studies examined the use of SRT to support writers with learning disabilities [14,15]. While Millar et al. found that writing rate was comparable to keyboarding, Nelson & Reynolds concluded that participants generally found SRT easier and faster than keyboarding [14,15]. The Nelson & Reynolds analysis concluded that SRT may be most effective for those with a high degree of frustration tolerance, good speech articulation, and those with oral skills that are stronger than writing skills [15]. Each of these studies had small enrollment with 5 or fewer participants, and qualitative analysis methods were unclear [14,15].

Two studies examined the use of SRT to transcribe lectures to support learners with disabilities [13,16]. A qualitative analysis provided strong anecdotal evidence that transcription of lecture material allowed some students to review what they were “actually missing” from lectures while others found it frustrating to sift through unedited texts of full lectures [13]. Ryba et al. found that students with learning difficulties reported a speech recognition lecture transcription system had potential as an instructional support more often than students who do not experience learning difficulties [16]. When using SRT for transcription, both studies support the need for a human to edit raw electronic transcripts for accuracy prior to use [13, 16]. These qualitative studies on using SRT as a transcription aid had higher enrollments compared to the studies on using SRT as a writing aid, though specific methods and details on frequency of use of SRT were unclear [13, 16].

SRT in Daily Living

SRT can be used as a method of access for devices that can control and manipulate the environment, including electronic aids to daily living (EADLs). These EADLs may operate media devices, open doors, operate adjustable bed functions and perform other tasks [4]. Although 4 articles considering speech recognition during daily living occupations were appraised, 3 were excluded because they were found not to meet inclusion criteria (they were not research studies or systematic reviews). Judge et al. performed semi structured interviews with individuals with neurological diagnoses who had been using daily living aids with SRT [17]. This retrospective analysis concluded that speech enabled electronic aids to daily living improved access, improved aesthetics, and increased perceived independence for individuals with disabilities [17].

SRT for General Computer Access

Four studies included in this analysis considered speech recognition for general computer access, without considering context or specific goals [18,19, 20, 21]. These studies included adult participants with neurological or rheumatic diagnoses, and involved using SRT for word processing, email communication and computer control [18,19,20,21]. It was found that tasks were completed in less time using SRT as compared to using a keyboard and mouse [18,20,21]. It was also determined that individuals with mild and moderate dysarthria can experience improvements in typing efficiency and productivity when using SRT [20, 21].

Fager et al. evaluated the use of a supplemental speech recognition system that combined features of speech recognition software and word prediction, and found that this system was more efficient, requiring fewer keystrokes and less time, than using keyboarding or word prediction alone [20]. Several studies that were excluded after review were found to be technical reports describing the process of developing a technology, and did not include analysis of an individual with a disability utilizing the SRT. DeRosier & Farber performed a retrospective qualitative analysis to determine psychosocial benefits of using SRT [19]. They found that individuals who used SRT reported increased feelings of competence, adaptability and self-esteem compared to before using SRT [19].

Discussion

This scoping review sought to determine, for individuals with disabilities, if SRT is effective for improving access when attempting to achieve educational, vocational and independent living goals. This analysis found and included eight articles that examined the use of SRT in primary, secondary and post-secondary educational contexts [9,10,11,12,13,14,15,16]. Only 1 article meeting inclusion criteria was found that examined the use of SRT in daily living activities [17]. No articles were found that met criteria examining the use of SRT in the context of vocational activities. Four included articles examined SRT without specifying context or participant goals [18,19,20,21].

Of the articles that were included in the analysis, only 4 had quasi-experimental designs or a comparison group [10,18,20,21]. These studies were characterized by small enrollments (between 5 and 23 overall participants). These studies were able to determine significant improvements in rate or efficiency of producing written work when comparing SRT to keyboard driven word processing [10,18,20].

Five of the studies performed retrospective analyses on individuals who were already using SRT [13,15,16,17,19]. These studies primarily used samples of convenience and conducted semi-structured interviews or surveys to understand the impact of SRT on their roles and tasks. The majority of these studies had modest enrollments as well (between 5 and 17 participants). Ryba et al. was an exception with 160 participants in a post-intervention survey, though it was noted that some of the participants did not have a disability [16].

It is of note that none of the studies included were considered to have rigorous experimental designs with randomization. Some have documented that the variation in the severity of disability and differences in desired outcomes and contexts make it a challenge to study assistive technologies in an empirical fashion [22]. Several theories that describe the assistive technology process, such as the Human, Activity, Assistive Technology (HAAT) model and the Matching Person and Technology (MPT) model emphasize the unique nature of each assistive technology and AT user pairing [4,23].

An assistive technology must meet the complex needs of the individual, capitalize on the strengths of the individual, be compatible with multiple layers of context, and successfully support participation in the chosen activity or occupation [4,23]. In considering these factors, one can appreciate the challenge in designing a meaningful study of an assistive technology with a standardized intervention and consistent measurable outcomes.

Several studies that were not included in this current analysis highlighted innovative ways in which SRT can be utilized to meet activity and occupational performance needs for individuals with disabilities. Tang et al. described the development and testing process for using SRT to monitor personal health outcomes by individuals with disabilities on personal digital assistants [24]. Wigmore et al. described the process in which they developed a tool that can use voice input to transcribe mathematical expressions [25]. Hussain et al. described the development of a speech recognition system that can detect parts of spoken Islamic prayer to alert deaf-blind worshippers to engage in specific prayer rituals through vibro-tactile alerts on a smartwatch or smartphone [26]. Although these articles did not meet criteria for inclusion, they highlight innovation and potential areas of further study in the use of SRT to support individuals with disabilities.

This scoping review finds that SRT, as compared to other device access, is an access method and compensatory strategy that may improve participation of individuals with disabilities in several contexts, including primary, secondary and post-secondary education settings, and in the community. The studies appraised in this review support the use of SRT as a practice option. This conclusion and support of SRT is timely, as SRT is included in an increasing number of digital devices, including smartphones, smart speakers, tablets, and laptop and desktop specific applications [3]. The ubiquity of this technology makes it readily available to trial and use in school, productivity/work and independent living contexts.

This review failed to find strong evidence supporting the use of SRT. Most of the studies reviewed were non-empirical or in the lower levels of evidence. There is an opportunity for assistive technology professionals and other providers who use assistive technology such as occupational therapists, speech and language pathologists and special educators, to continue to develop a rigorous body of knowledge for the use of SRT to meet educational, vocational and daily living needs. Theoretical frameworks guiding assistive technology intervention such as the HAAT model and MPT emphasize the importance of considering the unique strengths, needs, goals, preferences and contexts of individuals with disabilities when considering AT solutions [4,23]. The single case experimental design, as used by Millar et al. may provide a model at which to measure effectiveness of SRT [14, 27]. Clinicians and researchers can support evidence-based practice for SRT by conducting studies with repeated measures, comparison groups or experimental single-case designs, using valid and reliable outcome measures, and rigorous analyses.

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Table 1. Journals whose indexes were hand searched

The American Journal of Occupational Therapy
British Journal of Occupational Therapy
Canadian Journal of Occupational Therapy
The Australian Journal of Occupational Therapy
Assistive Technology
Assistive Technology Outcomes and Benefits
Journal of Rehabilitation and Assistive Technologies Engineering
Technology and Disability
JMIR Rehabilitation and Assistive Technologies
Journal of Enabling Technologies
Research and Practice for Persons with Severe Disabilities: The Journal of TASH

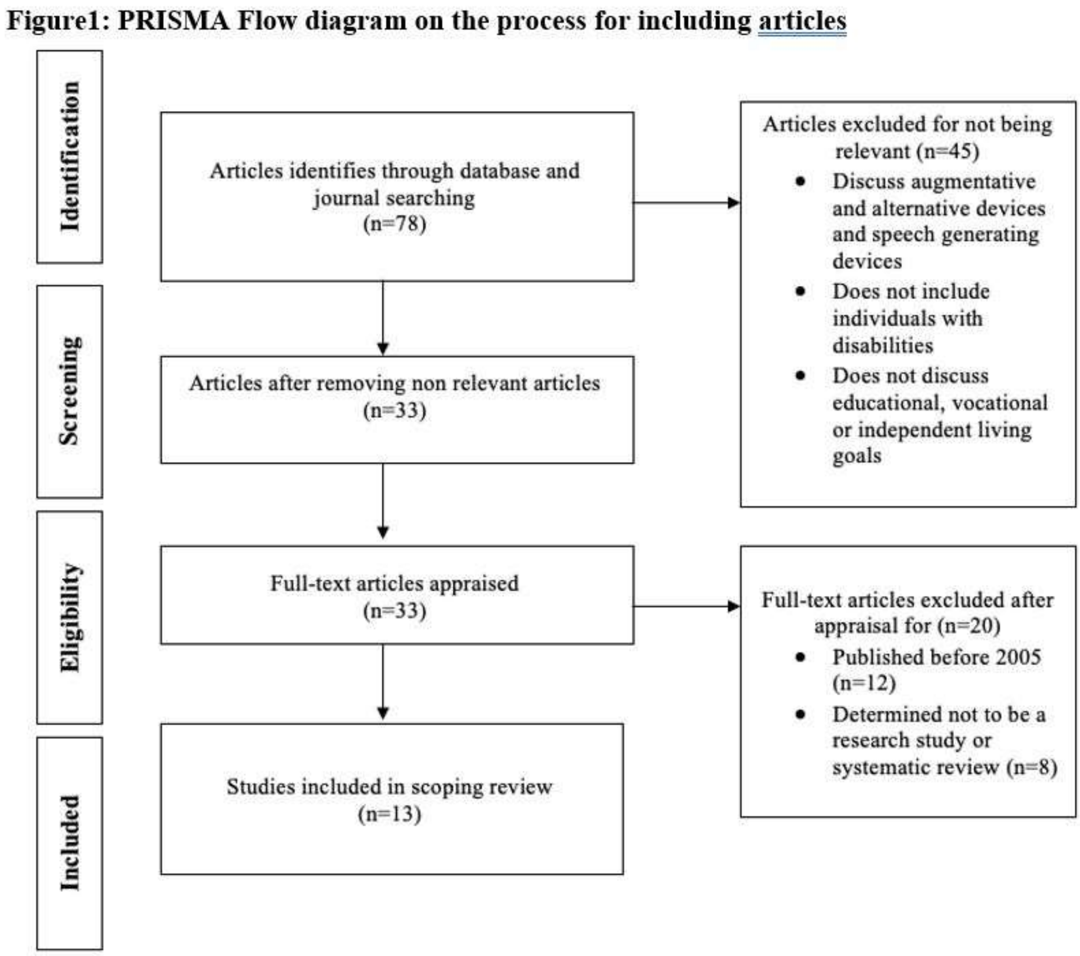
Table 2: Summary table for Speech Recognition Technology Scoping Review

Author, year	Study Design	Context	JBI Level Effectiveness	Population	Number of participants	Outcomes measured	Findings
Gardner, 2008, [9]	Nonsystematic Review	SRT in K-12	4a	n/a	n/a	n/a	Benefits of SRT include ease of access, reduced teacher assist, and improved generation of ideas. The problems with SRT are decreased accuracy rate for individuals with dysarthria, software recognition errors, time to learn new program/skill, and dictation feeling unnatural.
Garrett et al., 2011, [10]	Pre-test/Post-test Design	SRT in K-12	2.d	High school students with neurological diagnoses	5	5 variables of writing: fluency, accuracy, type of word error, recall of intended meaning, and length of the document	SRT was better for improved writing fluency and length compared to word processing across all participants. Accuracy was lower using SRT compared to word processing across all participants.
Maor et al., 2011, [11]	Systematic Review	SRT in K-12	3.b	n/a	n/a	n/a	SRT is shown to improve speech, reading, spelling and writing in students with learning disabilities between kindergarten and 12th grade.
Shadiev et al., 2014, [12]	Systematic Review	SRT in K-12	4.a	n/a	n/a	n/a	Earlier studies cite poor accuracy as a limitation with SRT. Newer studies demonstrate use of SRT as a universal design approach for all students. Literature themes include that SRT is useful for taking notes, completing homework and preparing for exams.

Bain et al., 2012, [13]	Post-intervention qualitative analysis	SRT in post secondary school	3.e	Post-secondary students with disabilities	17	Post intervention surveys. Analysis details not available.	SRT used to transcribe lectures. Provided anecdotal evidence on advantages and disadvantages of SRT. Advantages: help students understand what they are "actually missing" from lecture. Disadvantages: At risk students "frustrated and discouraged" with unedited transcripts with "too much lecture, not enough notes."
Millar et al., 2005, [14]	Single-subject alternating treatments	SRT in post secondary school	4.c	Post-secondary students with learning disabilities	3	Accuracy of transcription after editing, rate of transcription in words per minute, social validation measure	Accuracy for speech recognition was slightly lower than that of using a keyboard for all the participants. Rate of transcription was similar to the keyboard for 2 of the participants. 1 participant indicated they preferred speech recognition and the other 2 had no preference
Nelson & Reynolds, 2015, [15]	Phenomenological qualitative design	SRT in post secondary school	4.c	Post-secondary students with learning disabilities	5	Semi-structured interview on users experience for composing written materials with SRT.	College writers with learning disabilities, composing with SRT can be easier and faster than keyboarding. SRT may be most effective for those with a high degree of frustration tolerance, good speech articulation, and those with oral skills that are stronger than writing skills.
Ryba et al., 2006, [16]	Qualitative design	SRT in post secondary school	3.e	Post-secondary students, some with disabilities (number not specified)	160	Post-intervention survey and analysis of electronic correspondences.	SRT used to transcribe lectures. Students with learning difficulties report that a speech recognition lecture transcription system had potential as an instructional support mechanism more often than students who do not experience learning difficulties.
Judge et al., 2009, [17]	Qualitative design	SRT for daily living	4.c	Adults with neurological diagnoses	12	Semi-structured interview with coding.	Benefits of speech enabled electronic aids to daily living include improved access, improved aesthetics, and increased perceived independence.

Alcantud et al., 2006, [18]	Experimental design with comparison group	SRT general computer access	3.d	Adults with neurological diagnoses	23	Time to complete the dictation task, the number and kind of mistakes, and the time employed in their correction.	Overall user performance in writing tasks improved using SRT, and the time taken to complete the same task was reduced compared to using a keyboard.
DeRosier & Farber, 2005, [19]	Retrospective qualitative analysis	SRT general computer access	3.e	Adults with neurological and rheumatic diagnoses	10	Psychosocial outcomes with PIADS and QUEST assessments	According to the PIADS assessment participants reported increased feeling of competence, adaptability and self-esteem compared to before using SRT.
Fager et al., 2010, [20]	Quasi-experimental design	SRT general computer access	3.e	Adults with neurological diagnoses and dysarthria	7	Keystroke savings and SRT system performance	Evaluated prototype supplemented speech recognition system (SSR). There was a significant difference using the full SSR system compared to word prediction only for producing typed sentences. Keystroke savings were significantly higher when using the full SSR system than with word prediction alone.
Hird & Hennessey, 2007, [21]	Quasi-experimental design	SRT general computer access	2.c	Adults with neurological diagnoses	15	Time to complete training protocol, rate of improvement in words per minute	Participants demonstrated improvement in their dictation rate regardless of treatment type. Dysarthria severity does not preclude someone from some use of SRT.

Figure 1: PRISMA Flow diagram on the process for including articles



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