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Uses of assistive technology incorporating smart camera features in the rehabilitation of people living with disabilities: a scoping review

Anna Caute^a, Leila Mirza^a, Bundy Mackintosh^a, Reinhold Scherer^b and Victoria Joffe^a

^aSchool of Health and Social Care, University of Essex, Colchester, UK; ^bSchool of Computer Science and Electronic Engineering, University of Essex, Colchester, UK

ABSTRACT

Purpose: The objective of this scoping review was to explore the use of assistive technology incorporating smart camera features in the rehabilitation of people living with disabilities.

Materials and methods: This review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews. Articles were eligible if they considered assistive technology that incorporated at least one smart camera feature. Rehabilitation in any setting was considered. Research including participants of any age with any form of disability, both self-reported and diagnosed, was considered.

Results: 25 studies were included in the final synthesis. Most studies investigated assistive technology for visual impairment ($n=23$). The most explored devices were smartphones ($n=16$) and/or smart glasses ($n=13$). Most studies focused on text-to-speech ($n=22$) and/or object recognition features ($n=15$). One study focused on facial recognition for people with Alzheimer's disease and one on reading for children with dyslexia.

Conclusions: Assistive technology incorporating smart camera features has been used mainly in the rehabilitation of people living with visual disabilities. Reported rehabilitative outcomes included enhanced reading ability and improved daily living skills. However, there were technical limitations, usability issues and high financial costs associated with various devices.

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KEYWORDS

Rehabilitation; assistive technology; smart camera technology; disability; reading



> IMPLICATIONS FOR REHABILITATION

- Assistive technology incorporating smart camera features may enhance reading ability and daily living skills for people living with visual impairment.
- This technology is available in the form of smartphone apps and wearable devices.
- Its potential uses for people living with other types of disabilities remain under-explored in the literature.

Introduction

Over one billion people worldwide currently experience some form of significant disability [1]. The prevalence of disabilities is steadily rising due to an increase in the global ageing population and an increase in the prevalence of noncommunicable diseases [1,2]. Consequently, it is estimated that over three billion people worldwide will require assistive technology by 2050 [3] that is any equipment, software or products that improve or maintain people with disabilities' functional capabilities [4]. Rehabilitation aims to improve functioning and reduce disability for individuals living with health conditions and is crucial for minimising the barriers they experience when interacting with their environment [5]. Moreover, rehabilitation has broader societal benefits because it can facilitate participation in employment and promote home-based independence, leading to greater economic growth and reduced caregiver expenses [5].

Recently, there has been increasing interest in the role of technology in rehabilitation. One exciting advancement in assistive technology has been the integration of artificial intelligence (AI). Artificial intelligence refers to the use of digital technology to simulate the processes of human intelligence. It enables machines to perform tasks that would traditionally require human intelligence, such as analysis,

CONTACT Anna Caute  anna.caute@essex.ac.uk  School of Health and Social Care, University of Essex, Wivenhoe Park, ColchesterCO4 3SQ, UK.

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decision making and perception [6]. AI is already being used in the United Kingdom's National Health Service (NHS) to benefit both staff and patients – for example, using AI to analyse X-ray images supports radiologists in making assessments more quickly, which in turn allows more patients to be screened. In North East London, AI is being used to predict patients who are at risk of frequent accident and emergency department visits and provide them with preventative support [6]. AI is also being piloted in the NHS to decrease errors caused by human fatigue, automate repetitive tasks and reduce overall costs [7].

One specific form of AI is called computer vision, which allows computers to perceive and interpret visual information from the surrounding world. Through machine learning and neural networks, images and videos can be analysed, enabling systems to perform various visual perception tasks [8].

Another advancement in the assistive technology field is portable smart camera technology (p-SCT), which employs computer vision. This technology can be accessed through smartphones and wearable devices such as glasses. Mobile applications such as Seeing AI and Envision AI involve capturing digital photographs, enabling users to access several smart camera features including photo text to speech (i.e. narrating captured text aloud); object recognition and description (i.e. describing captured objects and surroundings); facial recognition and description (i.e. identifying captured faces and describing their features); and barcode scanning (i.e. using captured barcodes to identify corresponding products). p-SCT has the potential to be harnessed as a powerful rehabilitation aid for people living with various disabilities such as visual and communicative impairments. For example, they can support individuals to read items such as recipes; navigate their environment more easily by identifying and describing objects and scenes; participate fully in social interactions by identifying people; and access product information instantly. These apps are often free and are available on Android and iOS devices. They are able to read text in a range of languages and some also offer translation features, making them accessible to a wider range of people. AI integrations are also evident in voice assistants such as Siri and Alexa which are now widely used. They can support users by answering questions, sending messages, controlling home devices such as the radio and setting reminders.

In recent years, researchers have explored the use of p-SCT for people with visual impairments. Several studies have reported benefits following a period of rehabilitation using the OrCam MyEye 2.0 [9–11]. This is a wearable device that clips onto a pair of glasses and enables the user to access visual information through audio. It can read text aloud, recognise faces and describe objects and scenes. Several studies have found that the OrCam device significantly improves daily activities for visually impaired patients, especially reading [12]. Other studies have compared OrCam, which costs over £2000, with free smartphone apps, such as Seeing AI, and reported that the free apps were similar to OrCam in terms of their text reading capability, usability [13] and patient preferences [10].

While there is a small evidence base exploring the rehabilitative benefits of assistive technology incorporating smart camera features for individuals with visual disabilities, scant attention has been directed towards its potential utility for people experiencing other forms of disability. For example, having text read aloud while words are shown on the screen may be beneficial for people with cognitive or linguistic deficits, because information presented in multiple modalities may be easier to process [14,15]. Alternatively, the technology's ability to describe objects and people could facilitate memory and word finding in individuals with conditions such as dementia or aphasia. It could also support children with developmental disabilities to learn new words. Therefore, we carried out a scoping review to collate the literature and understand the overall landscape of research regarding p-SCT in the rehabilitation of various disabilities.

A preliminary search of MEDLINE, the Cochrane Database of Systematic Reviews and Joanna Briggs Institute (JBI) Evidence Synthesis [16] was conducted and no current or underway systematic reviews or scoping reviews on the topic were identified.

Review questions

The scoping review question was guided by the PCC framework as recommended by the JBI framework for scoping reviews. In this case, the "P" for population are people living with disabilities, the "C" for concept is assistive technology incorporating smart camera features and the "C" for context is rehabilitation.

The primary question was:

- How has assistive technology incorporating smart camera features been used in rehabilitation for people living with disabilities?

Sub questions were:

- Which types of people living with disabilities was the assistive technology used with?
- How was the smart camera technology used in rehabilitation?
- What benefits were reported from using assistive technology incorporating smart camera features?
- What, if any, barriers were reported to the use of assistive technology incorporating smart camera features?

Materials and methods

This scoping review was conducted in accordance with the JBI methodology for scoping reviews [17]. The JBI's template for scoping reviews was used to support the conduct and reporting of the review [18]. A protocol was written to guide this review and was published on the Open Science Framework (OSF) website (<https://osf.io/64nuj/>).

Inclusion criteria

Participants

This scoping review considered studies including participants of any age who are living with any form of disability. Both diagnosed and self-reported disabilities were included.

Concept

This scoping review considered any form of assistive technology that incorporates at least one smart camera feature. This could be photo text-to-speech, object recognition and description, facial recognition and description or barcode scanning. The technology may be used for assistive purposes or therapeutic uses.

Context

This scoping review considered studies that investigated the use of p-SCT for rehabilitation in any setting (e.g. at home, in a hospital or in supported living). In line with the WHO's [5] definition of rehabilitation, we included studies which explored whether p-SCT improved functioning or reduced disability for individuals living with health conditions. We included studies where a prototype device was trialled. All geographical locations were considered.

Types of sources

This scoping review considered quantitative, qualitative and mixed methods study designs. Literature reviews, opinion papers, and grey literature sources, such as conference papers and dissertations, were also considered for inclusion in this scoping review.

Search strategy

The search strategy aimed to locate both published and unpublished studies. To assist with the development of the search strategy, we received support from an academic librarian. An initial limited search of PubMed and CINAHL was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy for each database used. Following the development of the full search strategy, a three-step search strategy was then utilised in this review. Firstly, PubMed, CINAHL, EMBASE

and PsycINFO were searched for articles. Next, the articles were assessed according to title and abstract with irrelevant articles excluded. Full texts were retrieved for the remaining articles and these were assessed for eligibility. The final search was carried out on 04.09.2025.

Studies published in English, French and German were considered. Searches were limited from 2009 onwards, because this was when smart camera technology became available on the market. Sources of unpublished studies and grey literature searched were Open Access Theses and Dissertations, EBSCO Open Dissertations and ProQuest. Hand-searching of studies' reference lists was also conducted.

The full electronic search strategy for all databases is outlined below:

"smart camera" OR "computer vision" OR "mobile technology" OR "assistive technology" OR "seeing ai"
OR "envision ai"

AND

"impair*" OR "disorder*" OR "disab*" OR "difficult*"

AND

"text to speech" OR "print to speech" OR "speech synthesis" OR "narration" OR "object recognition" OR
"scene description" OR "object description" OR "object detection" OR "facial recognition" OR "automatic
face detection" OR "barcode scan" OR "barcode reader" OR "barcode identification" OR "QR code scan"

AND

"rehab*" OR "therap*" OR "treatment" OR "recovery"

Selection of sources of evidence

Following the search, all identified citations were collated and uploaded into Rayyan, a type of web-based software that supports screening for literature reviews. Duplicates were removed. Titles and abstracts were screened by two independent reviewers (LM and KK, an MSc student) for assessment against the inclusion criteria. Potentially relevant sources were retrieved in full, and the full text of selected citations were assessed in detail against the inclusion criteria by the two reviewers (LM and KK). Reasons for exclusion of sources of evidence at full text that did not meet the inclusion criteria were recorded. Any disagreements between the reviewers during the selection process were resolved through discussion, or with a third reviewer (AC).

Data charting and data items

Data was charted by two independent reviewers (LM and AC) using a data extraction form adapted from JBI by the researchers (see [Appendix](#)). The data extraction form was tested by the two reviewers on a sample of 10 papers and was refined following discussion. The form documented the following information for each paper: title, author/s, year of publication, journal/publication, country where research was carried out, study objective, type of study/research design, data collection, sample, number of participants, age range of participants, details about how the technology was used in rehabilitation, details about the technology (type of device and smart camera features used) and key findings related to the review questions. Both reviewers extracted data for each article, then met to compare results. Any disagreements between the reviewers were resolved through discussion.

Synthesis of results

Due to the wide variety of research designs included in this review, narrative synthesis was used to describe how assistive technology incorporating smart camera features has been used in the rehabilitation of people living with disabilities, the benefits and barriers reported. Tabulation was used to present information about study characteristics, participant characteristics, technology characteristics, how the technology was used, outcomes, useful features, usability issues, facilitators and barriers.

Results

The search process identified 463 records, which reduced to 379 records after duplicates were removed. Nine records were identified from hand-searching reference lists. 379 records were assessed according to

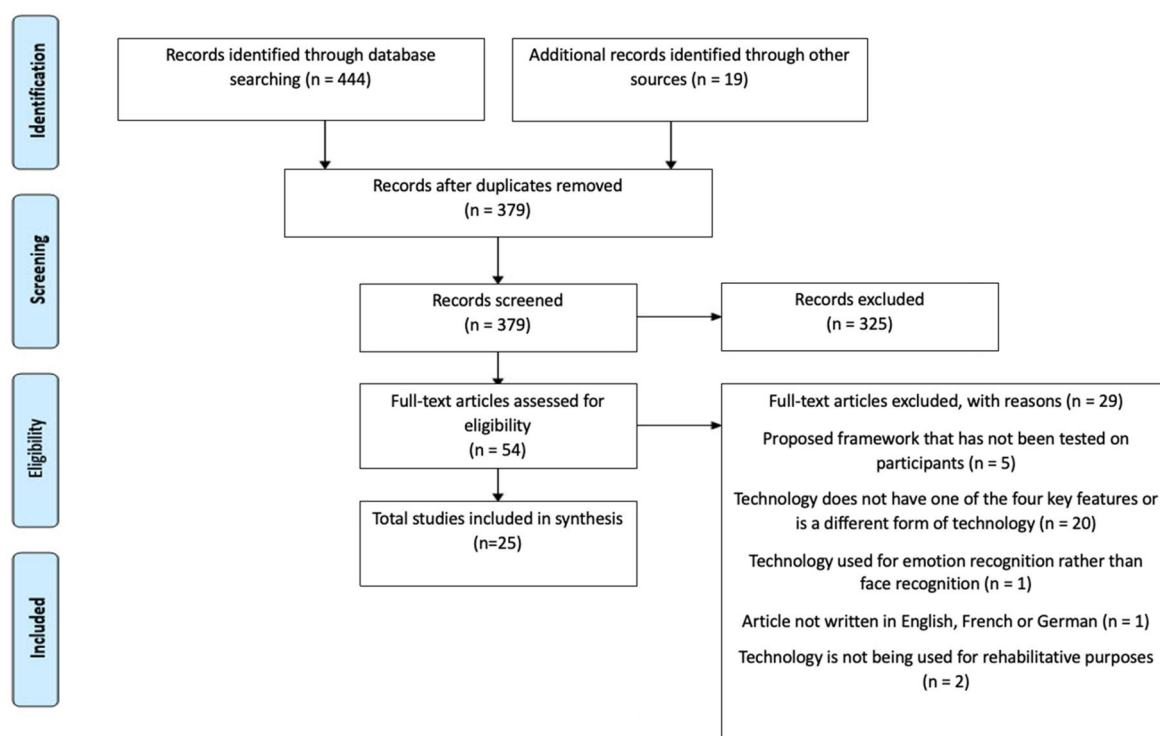


Figure 1. PRISMA flow chart.

title and abstract, and 325 of these records were excluded. 54 full-text articles were then assessed. 29 of these were removed (see reasons in Figure 1) and 25 total articles were included in this review. 7 of the included articles were grey literature and these were all conference proceedings. There was a 91% agreement rating between reviewers on title and abstract screening. There was an 83% agreement rating between reviewers on full-text inclusion. Disagreements were resolved through discussion between the two reviewers (LM and KK). Only one decision at the screening stage involved discussion with the third reviewer (AC). The search process is illustrated in a PRISMA diagram in Figure 1.

Study characteristics

The studies included in the final synthesis used a variety of methodologies to address different objectives. We have grouped the articles into four broad categories: reviews (group one, $n=4$), studies evaluating existing technology (group two, $n=10$), studies investigating novel assistive devices (group three, $n=8$) and studies reporting on clinical practice or user experience (group four, $n=3$). Ten of the articles were carried out in the USA. The other articles' authors were from 14 countries in Asia, South and North America, Europe and the Middle East. One article was written in German and all others were written in English. These characteristics are summarised in Table 1.

Participant characteristics

Of the 15 studies that reported participants' ages, 14 were carried out with adult participants, with ages ranging from 18 to 92. One study investigated children with dyslexia [27].

Of the 25 studies, 23 focused on assistive technology for people with visual impairments. These visual impairments varied in severity and included congenital blindness, glaucoma and retinal dystrophies. Participants from one study had visual impairment and/or aphasia, including four participants with visual impairment only and two with visual impairment and aphasia [24,25]. One study [31] investigated assistive technology for people with Alzheimer's disease and one investigated a handheld reading device for children with dyslexia [27].

Table 1. Study characteristics summary.

Group	Article (title, authors and date)	Study location	Study methodology	Study objective
1	Celik and Rohschrneider [19]. "Assistive technology: New possibilities for visual impairment rehabilitation." Patel and Parmar [20]. "Assistive device using computer vision and image processing for visually impaired; review and current status." Pundlik et al. [21]. "Impact of Apps as Assistive Devices for Visually Impaired Persons"	Germany India USA	Comprehensive review article and opinion piece discussing a range of existing electronic aids. Review article; presently available vision assistance devices were explored. Review article; literature review and search of available apps.	To review available electronic vision aids and make recommendations for using these in ophthalmological rehabilitation. To review vision substitution devices based on computer vision and image processing, particularly those requiring coding and sensors. To survey the literature on vision assistance apps and carry out a survey of available apps, via an online search, a literature search using PubMed and an app store search. To review the literature regarding vision assistance apps and explore commercial apps.
2	Souza et al. [22]. "Intelligent environments and assistive technologies for assisting visually impaired people: a systematic literature review" Moisseiev and Mannis [9]. "Evaluation of a Portable Artificial Vision Device Among Patients With Low Vision" Neat et al. [23]. "Scene Text Access: A Comparison of Mobile OCR Modalities for Blind Users" Waisbourd et al. [11]. "The Effect of an Innovative Vision Simulator (OrCam) on Quality of Life in Patients with Glaucoma" Caute et al. [24] and Subramanian et al. [25]. "Roving reading: Exploring the use of portable smart camera technologies for adults with visual impairments and/or language impairment following stroke or other forms of brain injury." Granquist et al. [13]. "Evaluation and Comparison of Artificial Intelligence Vision Aids: OrCam MyEye 1 and Seeing AI" Nguyen et al. [10]. "Artificial vision: the effectiveness of the OrCam in patients with advanced inherited retinal dystrophies" Amore et al. [12]. "Efficacy and Patients' Satisfaction with the ORCAM MyEye Device Among Visually Impaired People: A Multicenter Study" van der Aa et al. [26]. "Objective performance and usability of artificial intelligence (AI) devices and mobile apps for people with vision impairment" Ross [27]. "Impact of OrCam Learn on reading comprehension." Seiple et al. [28]. "Performance on Activities of Daily Living and User Experience When Using Artificial Intelligence by Individuals With Vision Impairment"	Brazil USA USA USA UK USA Netherlands Italy/Canada/ Mexico/Brazil USA UK US/ Netherlands	Systematic literature review: 101 studies included. Prospective pilot study; compared performance on a test of activities of daily living in three conditions: best corrected visual acuity with and without their own low vision aids and using OrCam. Comparative study comparing three apps' ability to locate and read text in indoor environments. Participants completed questionnaires and an exit interview. Prospective observational study; assessed participants' quality of life before and after using the OrCam device for one month. Exploratory study; investigated the potential benefits of OrCam MyEye2. The study also explored the benefits of free comparator apps available on smartphones. Comparative study; participants completed reading activities using different devices. Prospective observational study; participants completed questionnaires before and after using OrCam for 5weeks Prospective multicentre study; participants completed tasks resembling everyday life with and without the OrCam MyEye Device. Cross-sectional, counterbalanced study; participants carried out everyday tasks related to vision. Efficacy study; explored whether OrCam Learn, a handheld reading device, improved reading comprehension and its social validity. Cross-sectional, counterbalanced, cross-over study comparing two apps (Seeing AI and Lookout) and two smart glasses (OrCam and Envision Glasses).	To investigate how Intelligent Environments (IE) and AT have been used to support people with visual impairment. It explores the challenges of developing IE and AT systems for people with visual impairment, the technologies and devices used. To evaluate the usefulness of OrCam for people with low vision. The study also explored the impact of training- participants were assessed before training, immediately after training and after using OrCam for one week. To compare Seeing AI's Short Text feature to two custom apps that help blind users find text using vibrational feedback. To evaluate the impact of OrCam on vision-related quality of life for people with visual impairment (legal blindness and end stage glaucoma). To identify the most suitable available app. To explore how participants used OrCam and the app after brief training. To compare the text-to-speech features and usability of two artificial intelligence vision aids, OrCam MyEye 1 and Seeing AI. To explore the impact of OrCam MyEye 2.0 on quality of life and rehabilitation needs of people with visual impairments. To evaluate the usability and satisfaction with OrCam MyEye for visually impaired people carrying out real-world tasks. To compare the performance and usability of four AI-based devices/apps (Seeing AI, Envision AI, Lookout, OrCam). To compare students' reading comprehension with and without OrCam Learn. To explore students' experience of using OrCam Learn. To compare the technologies' performance on reading, searching and identifying tasks. To explore the usability and acceptability of the different technologies.

(Continued)

Table 1. Continued.

Group	Article (title, authors and date)	Study location	Study methodology	Study objective
3	Tekin and Coughlan [29]. "A Mobile Phone Application Enabling Visually Impaired Users to Find and Read Product Barcodes"	USA	Proof of concept study testing a prototype app	To explore how well an app could support a blind participant to locate and read barcodes on common products.
	Stearns et al. [30]. "The Design and Preliminary Evaluation of a Finger-Mounted Camera and Feedback System to Enable Reading of Printed Text for the Blind."	USA	User study- preliminary evaluation of prototype device.	To design and evaluate a prototype of HandSight. The study evaluated three types of feedback- audio only, haptic only, combined audio+haptic.
	Fardoun et al. [31]. "Recognition of familiar people with a mobile cloud architecture for Alzheimer patients."	Spain	Evaluation of a prototype and small-scale study.	To evaluate a prototype smartwatch device for people with Alzheimer's disease that uses facial recognition to help them to remember personal details of familiar people.
	Shilkrot et al. [32]. "FingerReader: A Wearable Device to Explore Printed Text on the Go."	USA/ Singapore	Technical evaluation of a novel finger-worn reading device, focus groups and user feedback sessions.	To evaluate the usability of FingerReader: Technical evaluation explored accuracy of text reading, focus groups explored participants' reading habits, current use of AT and views about prototypes of Finger Reader. User evaluations analysed participants' use of FingerReader and how effective it was for reading.
	Banf et al. [33]. "PictureSensation – a mobile application to help the blind explore the visual world through touch and sound."	Germany	User study; a blind participant explored images presented on a phone by touching different sections of the screen and listening to descriptions.	To investigate whether the Picture Sensation app can support people with visual impairment to understand visual images via touch and audio.
	Awad et al. [34]. "Intelligent eye: A mobile application for assisting blind people."	Lebanon	Small-scale pilot study; participants carried out activities using a mobile app and provided feedback about it.	To present the Intelligent Eye app and report on user feedback.
	Chen et al. [35]. "A Novel Approach to Wearable Image Recognition Systems to Aid Visually Impaired People."	China	Small-scale pilot study.	The authors aimed to create an affordable yet effective wearable smart glass device to support visually impaired users with identifying objects, recognising faces and reading.
	Chatpaitoon and Itthipanichpong [36]. "Effect of optical text recognition (OCR) and text-to-speech (TTS) smartphone app on vision-related quality of life in visually impaired people."	Thailand	Prospective observational study; participants tested out CU Eye Reader app and answered questions at baseline and after one month.	To investigate usage and whether the app improves vision-related quality of life.
	Dockery and Krzystolik [37]. "The Use of Mobile Applications as Low-Vision Aids: A Pilot Study."	USA	Convenience sample telephone survey of patients at a low vision centre who were known to use low-vision apps.	To identify the most commonly used and highly rated apps designed to support visually impaired users.
	4	Sorber et al. [38]. "Incorporating Wearable Technology in Low Vision Rehabilitation: Case Reports Reviewed."	USA	Case reports; patients were given various wearable assistive aids to support rehabilitation.
Bhagat et al. [39]. "Accessibility evaluation of major assistive mobile applications available for the visually impaired."		India	Surveys of blind and low vision users in developing countries.	To gain insights into users' preferences and experiences of using AI and computer vision-based recognition apps.

Table 2. Participant characteristics summary.

Group	Article (authors, date)	Sample	Number of participants	Age range
1	Celik and Rohrschneider [19]	Visually impaired people	Not reported	Not reported
	Patel and Parmar [20]	Visually impaired people	Not reported	Not reported
	Pundlik et al. [21]	Visually impaired people	Not reported	Not reported
2	Souza et al. [22]	Visually impaired people	Not reported	Not reported
	Moisseiev and Mannis [9]	Visually impaired people	12	27 to 93
	Neat et al. [23]	Blind people	7	Mean 54, range 23–70
	Waisbourd et al. [11]	Patients with legal blindness and end stage glaucoma	27	Mean age 62, range- 22 to 92
	Caute et al. [24] and Subramanian et al. [25]	People with visual impairment and/or aphasia and reading difficulties.	7	Not reported
	Granquist et al. [13]	Visually impaired people	7	26 to 67
	Nguyen et al. [10]	Patients with either retinitis pigmentosa or cone-rod dystrophies	20	Mean age 47.6
	Amore et al. [12]	Visually impaired people	100	19 to 90
	van der Aa et al. [26]	Visually impaired people	30	Not reported
	Ross [27]	Children with dyslexia	32	10–13
3	Seiple et al. [28]	Visually impaired people	25	Mean age 64, range 30–83
	Tekin and Coughlan [29]	Blind person	1	Not reported
	Stearns et al. [30]	Visually impaired people	4	43 to 64
	Fardoun et al. [31].	People with Alzheimer's disease	41	55 to 72
	Shilkrot et al. [32]	Congenitally blind people	14 (4 for technical evaluation, 7 in focus groups, 3 for qualitative evaluation)	Not reported
	Banf et al. [33]	Congenitally blind person	1	55
	Awad et al. [34]	Visually impaired people	10	Not reported
	Chen et al. [35]	Visually impaired people	23 (4 in study one, 19 in study two)	20 to 60
	Chatpaitoon and Itthipanichpong [36]	Blind and severely visually impaired people	11	18 to 64
	4	Dockery and Krzystolik [37]	Visually impaired people	11
Sorber et al. [38]		Legally blind patients	4	64 to 87
Bhagat et al. [39]		Blind and visually impaired people	Not reported	Not reported

Sample sizes varied, ranging from single case studies to a larger study with 100 participants. Only six studies included 20+ participants. The four review articles did not report on the number of participants in the articles they reviewed. Participant characteristics are summarised in [Table 2](#) below.

Technology characteristics

The most commonly studied devices were smartphones ($n=16$) and smart glasses ($n=13$), with much less focus on tablets, smartwatches and hand-held or mounted devices. Orcam's smart glasses were the most widely investigated device with 10 studies exploring their use. Most studies ($n=15$) focused on one type of device. Other studies reviewed or compared two or more different devices. For example, four studies compared smartphone apps with wearable smart glasses [13,24–26,28].

Some studies focused on one smart camera feature whereas others explored multiple features. The features investigated were text-to-speech ($n=22$), object recognition ($n=15$), facial recognition ($n=11$) and barcode scanning ($n=7$).

The types of devices and smart camera features explored in each article are summarised in [Table 3](#).

How smart camera technology was used in rehabilitation

The way technology was used in rehabilitation and the associated rehabilitation outcomes are summarised in [Table 4](#).

Types of studies

There was great variation among the studies in how the assistive technology was investigated and the extent of rehabilitation provided. Some studies reported on the use of technology by people with disabilities during prototype testing [34], whereas others provided training and ongoing support, loaned devices and monitored use of the devices over a longer period [9]. Among studies reporting on use of

Table 3. Technology characteristics summary.

Group	Article	Type of device(s)					Smart camera feature(s)			
		Smart phone	Tablet	Smart watch	Smart glasses	Hand held or mounted device	Text to speech	Object recognition	Facial recognition	Barcode scanning
1	Celik and Rohrschneider [19]	✓	✓		✓	✓	✓	✓	✓	✓
	Patel and Parmar [20]	✓			✓		✓	✓	✓	
	Pundlik et al. [21]	✓					✓	✓	✓	✓
	Souza et al. [22]	✓			✓		✓	✓		
2	Moisseiev and Mannis [9]				✓		✓	✓		
	Neat et al. [23]	✓					✓			
	Waisbourd et al. [11]				✓		✓			
	Caute et al. [24] and Subramanian et al. [25]	✓			✓		✓			
	Granquist et al. [13]	✓			✓		✓			
	Nguyen et al. [10]				✓		✓	✓	✓	✓
	Amore et al. [12]				✓		✓	✓	✓	
	van der Aa et al. [26]	✓			✓		✓	✓	✓	
	Ross [27]					✓	✓			
	Seiple et al. [28]	✓			✓		✓	✓	✓	✓
3	Tekin and Coughlan [29]	✓					✓			✓
	Stearns et al. [30]					✓	✓			
	Fardoun et al. [31]	✓		✓					✓	
	Shilkrot et al. [32]					✓	✓			
	Banf et al. [33]	✓						✓		
	Awad et al. [34]	✓						✓		
	Chen et al. [35]				✓		✓	✓	✓	
	Chatpaitoon and Itthipanichpong [36]	✓					✓			
4	Dockery and Krzystolik [37]	✓					✓	✓	✓	✓
	Sorber et al. [38]				✓		✓	✓	✓	✓
	Bhagat et al. [39]	✓					✓	✓		

assistive technology, Dockery and Krzystolik [37] surveyed real-life use of smart-camera technology, while Sorber et al. [38] reported on clinical case studies using wearable head-mounted devices. The four review studies gave an overview of a range of different apps and devices and reported on how these had been used in rehabilitation. Their conclusions varied with some highlighting the technology's potential [19,22] while others identified limitations in the evidence base [21] or in the technology available [20].

Outcomes of rehabilitation

The most commonly reported rehabilitative gains were enhanced reading skills. These were observed across a range of devices, including commercially available wearable devices (e.g. OrCam) and smart-phone apps (e.g. Seeing AI, Be My Eyes), as well as novel technology in development, for example the CU Eye Reader app [36] and the wearable FingerReader device [32].

Another reported benefit of using smart-camera technology was improved object and recognition, including using OrCam to identify different brands of cereal [9] or using novel smart glasses to identify everyday objects [34,35]. Although facial recognition and barcode scanning were less explored, a few exploratory studies investigated these features through novel apps or devices. Fardoun et al. [31] developed a prototypal smartwatch for adults with Alzheimer's disease designed to recognise people's faces, but the accuracy and impact of using it was not reported. Tekin and Coughlan [29] designed an app to help a blind volunteer to recognise everyday grocery items through barcode scanning. The participant was able to access product information for 7 out of 10 products.

Comparison of different technologies

Several studies compared different assistive technologies, either through carrying out surveys or asking participants' views. Dockery and Krzystolik's [37] survey asked respondents for their views about different apps and found Seeing AI and Be My Eyes were the most popular. This survey also indicated that most respondents use several different apps rather than relying on a single app or device. However, the sample was small ($n=11$) and may not be representative as the respondents all attended a low vision centre.

Table 4. Summary of how technology was used, rehabilitation outcomes, useful features, usability issues, barriers and facilitators to using the technology.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
1	Celik and Rohrschneider [19] Technology: a range of electronic visual aids	To facilitate reading, shopping, orientation and navigation.	The article describes how a range of electronic visual aids can be used in rehabilitation. The authors describe specific devices, their functions and situations where they might be used, e.g. reading devices could be used in school and further education settings. They give advice about how to use the devices in clinical practice including tips about factors to consider when selecting devices for patients.	AT for reading enables the user to listen to text, adjust the reading speed and volume and store texts to read again later. Multifunctional smartphones are replacing individual devices. This means that aids are becoming smaller, more inconspicuous and less stigmatising.	Clinicians should consider a person's needs, their age and previous technology knowledge and experience and financial resources when selecting a suitable aid. They argue that younger people are more likely to own a smartphone or tablet and so could use these rather than more expensive specialist devices, but that it may be more challenging for older people to learn to use electronic visual aids. Some bespoke mobile reading devices require compatibility of hardware and software components of the computers.
	Patel and Parmar [20] Technology: a range of vision substitution devices using computer vision and image processing.	To facilitate independence in daily activities involving communication and mobility, e.g. crossing the road.	A range of assistive devices is available on the market. The review discusses the potential uses, benefits and limitations of a selection of devices for people with visual impairments. It highlights inequitable access to such devices in developing countries, due to some devices not being commercially available and limited technology knowledge of users.	OrCam: small and portable, no internet connection required, real time output, thoroughly tested and commercially available. Intelligent eye: app used on smartphone, so it is cost-effective and there is no need to carry an additional device, no internet connection required.	Intelligent eye recognises an object and displays the word but does not read the word aloud which is less beneficial for people with visual impairments. Its developers claim it is commercially available, but unclear where app can be downloaded from. Limited testing with visually impaired users. Some devices are not commercially available in developing countries. Access may also be impeded by limited technology knowledge of users.
	Pundlik et al. [21] Technology: a range of vision assistance smartphone apps	Vision assistance, including reading, navigation, object recognition/description and scene magnification and entertainment apps designed for people with visual impairment.	The review reports that there is limited evidence for the real-world impact of assistive devices for visual impairment, particularly for electronic visual aids. They describe research as falling into four categories: user surveys, lab and clinical case studies, naturalistic studies and randomised clinical trials (RCTs). There were no published RCTs. User surveys found people with visual impairment increasingly used smartphones and preferred these to specialist assistive devices for daily tasks. The majority found smartphone assistive apps useful and accessible.	Apps are widely available, accessible, affordable and versatile. The ubiquity of smartphones means that users don't stand out, as they would using a specialist device.	There have been user reviews of apps, but few scientifically rigorous investigations of the usability of apps. Although apps such as Seeing AI use advanced AI, they are not sufficiently intelligent to understand users' needs. In order to use object recognition features the user needs to be able to point a camera at an object. This may be challenging for people with severe visual impairment.
	Souza et al. [22] Technology: a range of intelligent environments and assistive technologies for visual impairment	To facilitate reading and navigation.	The review describes a range of devices designed to assist visually impaired users with reading and navigation. It argues that the technology has potential to facilitate independent living and improve quality of life for people with disabilities.	Miniaturisation of technology has enabled development of small and portable/ wearable devices.	Challenges for developers include designing accessible interfaces, achieving real-time performance, high costs and the high energy consumption of devices.

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Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
2	Moisseiev and Mammis [9] Technology: OrCam smart glasses	To facilitate daily living activities, including reading and recognising products and money.	<p>Participants' ability to use OrCam improved significantly after training from an experienced instructor- from 2.5 to 9.5/10 on 10-item functional test. There was no further significant improvement after participants had used it for a week.</p> <p>Seven participants also carried out the test with low vision aids. Their performance was significantly better with low vision aids than without, and significantly better with OrCam than with low vision aids.</p> <p>At the end of the study, participants reported that OrCam was a useful aid. They said they would use it in their daily lives and would recommend it to other people with low vision.</p>	<p>OrCam is portable and has good processing speed, so can read and recognise objects immediately. The reading aloud speed can be adjusted. Participants found it simple to understand and easy to use for reading, product and facial recognition, reading/recognising distant signs.</p>	<p>OrCam has some technical limitations: it cannot recognise special fonts and may be unable to recognise text if the contrast with its background is poor or under insufficient lighting conditions.</p>
	Neat et al. [23] Technology: Seeing AI and two custom-built smartphone apps using optical character recognition	Apps were used to locate and read text in corridors and open spaces.	<p>Participants used varied strategies to locate text in the indoor environment. All but one found vibrational feedback of custom apps helpful.</p>	<p>Facilitators included vibrational feedback to help locate text.</p>	<p>Barriers identified included long processing time and different snippets of text being read while trying to frame the text, rather than the whole sentence being read aloud.</p>
	Waisbourd et al. [11] Technology: OrCam smart glasses	To facilitate reading and exploring the impact on quality of life	<p>After one month of using OrCam MyEye 1, 74.1% of participants reported an increase in their overall quality of life and most (88.9%) were satisfied or highly satisfied with it. They were able to read independently using OrCam when in controlled settings but found it harder to use in outdoor settings where it was more difficult to locate the text, e.g. reading street signs. Most participants used the device to read books and other paper documents and found it easier to read with OrCam. There were improvements in "near vision" subscale of a visual function questionnaire. However, it did not significantly increase their reading speed. The majority did not find it useful for grocery shopping.</p>	<p>OrCam's was particularly useful for reading books and paper documents.</p>	<p>Participants found it difficult to get started using OrCam and that it required a lot of trial and error. However, after one month, most participants found it easy/very easy to use. Participants found it more challenging using the device when text was harder to locate (e.g. street signs). Participants with some degree of vision were more able to align the device with the text. OrCam did not work well in low light conditions.</p> <p>The high cost of OrCam is a barrier for many potential users.</p>
	Caute et al. [24] and Subramanian et al. [25] Technology: OrCam smart glasses, Seeing AI and KNFB Reader smartphone apps	Participants were trained to use OrCam, Seeing AI and KNFB Reader. They used each technology for two weeks and then reported how they had used it, barriers and facilitators they had experienced.	<p>Seeing AI was selected as the preferred app for Apple phones and KNFB Reader was selected as the preferred app for Android phones.</p> <p>Participants used both technologies for a range of reading activities across a variety of contexts in their everyday lives, including reading books, newspapers, menus, ingredients, signs, letters and timetables.</p>	<p>Participants identified OrCam's high quality voice as a key benefit.</p> <p>The apps highlighted text as it was read aloud which facilitated reading. The apps were free (Seeing AI) or had a small cost (KNFB Reader).</p>	<p>Participants reported difficulties operating OrCam, in particular directing the camera accurately to text. OrCam did not perform well in low light conditions. It is expensive.</p> <p>Using the apps reduced the phone's battery life, which was a barrier to using them in the community.</p>

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Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
	Granquist et al. [13] Technology: OrCam smart glasses, Seeing AI smartphone app	Everyday reading tasks using OrCam and Seeing AI.	The comparison of OrCam and Seeing AI showed that the two devices were similar in terms of accuracy achieved in text recognition (over 95%) and time taken to complete tasks. However, participants completed more tasks successfully using OrCam (71%) than Seeing AI (55%). Participants thought both aids would be helpful for daily activities involving reading.	Seeing AI and OrCam both facilitate reading of hardcopy text. Seeing AI is free and can read in low light conditions using a flash function. It can read text in different orientations (e.g. sideways). OrCam can be used hands-free. It is operated using a simple button push or finger gesture, which may be easier to learn than the gestural interface for VoiceOver on a smartphone.	Seeing AI requires the user to manually position and align the camera, which made it less intuitive for some users. OrCam is expensive. OrCam was unable to read text in low light conditions or when text was presented sideways or upside down. Both devices struggled to read text when the font or formatting was unusual, e.g. text on a medicine bottle. Both had less contrast sensitivity and visual acuity than the human eye, but Seeing AI performed better for low contrast text.
	Nguyen et al. [10] Technology: OrCam smart glasses	Participants were trained to use OrCam features by trained instructors. They were lent an OrCam for 5 weeks for personal use with no restrictions.	Significant improvements were observed in the 'reading' rehabilitation goal and in the "near activity" subscale of a visual function questionnaire.	OrCam's main benefit was facilitating reading. Useful features included text-to-speech, portability, hands-free operation, colour and barcode recognition, Bluetooth connectivity with earpieces.	85% of participants did not continue using the device after study completion. The main reasons were that they had other text-to-speech products such as smartphone apps, the cost of OrCam, that it lacked useful features such as navigation, that the device was heavy on lightweight glasses frame. Most participants did not use the facial and object recognition features, either because they were not useful or due to lack of time to learn to use these features and train the device to recognise people and objects. Technical limitations reported were difficulties with text recognition in low light, short battery life, and lack of connectivity with smartphone.
	Amore et al. [12] Technology: OrCam smart glasses	Participants carried out a series of daily living tasks using OrCam: reading a newspaper article, a book page and digital screen; reading near and distant signs, recognising currency, faces and colours. They were supported by an orthoptist who provided technical support if needed. Questionnaires assessed usability, patients' impression of change, satisfaction with AT and impact of using it.	Participants were generally satisfied with OrCam's performance and most reported improvements when using it. They completed more daily living tasks with than without OrCam. OrCam significantly enhanced reading and face, money, colour and product recognition abilities. Nearly all participants successfully read a newspaper article (88%), read on a screen (87%), read a book page (97%), and read a distant sign (77%). Younger patients were more likely to benefit, but age did not strongly influence use of OrCam and most older adults were satisfied and reported no problems using it. OrCam was particularly beneficial for patients with central vision loss (compared to peripheral visual field loss).	Participants reported that OrCam was effective and easy to use. The authors report that they were able to use the device immediately after being introduced to it. They used it to read, recognise money and faces.	No barriers reported.

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Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
	van der Aa et al. [26] Technology: Orcam smart glasses, Seeing AI, Lookout and Envision AI smartphone apps	Vision-related daily activities were carried out with and without the devices. No training or instruction in using the devices was reported.	The authors report which devices/apps performed better than the baseline with no device for each task. All devices/apps facilitated reading a newspaper article and invoice. Orcam and Seeing AI facilitated reading a table of contents. Envision AI, Lookout and Seeing AI facilitated reading a handwritten grocery list, street sign, dollar bill and medicine bottle. Envision AI, Lookout and Seeing AI facilitated identifying a room. Seeing AI was the only app that facilitated identifying a landscape and colours. Reading a TV guide was the only task that was not facilitated by using any of the devices/apps. Students' reading comprehension improved significantly when using Orcam Learn. 94% of students preferred reading with Orcam Learn to reading independently with no support and 84% preferred it to human support.	The apps/devices generally performed better on reading tasks, but apps/devices had different strengths and limitations. The authors recommend using the findings to help select devices/apps for patients that perform best on relevant tasks.	None of the apps/devices facilitated reading a TV guide, suggesting they struggled to read text in multiple rows and columns. Lookout and Orcam did not facilitate several of the searching and identifying tasks.
	Ross [27] Technology: Orcam Learn, a handheld reading device	Firstly, students read passages on paper and answered reading comprehension questions. They were then shown how to use Orcam Learn and their reading comprehension with the device was evaluated. Finally they completed a survey about Orcam Learn.		Students reported feeling comfortable using Orcam Learn and felt it would help them read independently.	None reported.
	Seiple et al. [28] Technology: Orcam and Envision smart glasses, Seeing AI and Lookout smartphone apps	Four technologies were used for reading, searching and identifying tasks. Participants received training on each technology.	Participants were able to complete more tasks with all the technologies compared to using no technology at baseline. Participants felt that all the devices would be most useful for reading tasks. Satisfaction was highest for Seeing AI (5/5), followed by Orcam (4/5) and Envision/Lookout (3/5). Seeing AI was also observed to have the best overall performance across tasks. Participants with more severe visual impairment showed greater improvement in task performance.	Overall, Seeing AI was the most usable and acceptable of the four technologies.	None reported.

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Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
3	Tekin and Coughlan [29] Technology: prototype smartphone app	Identifying common household items using a prototype smartphone app.	Following a brief training session, the blind participant successfully found barcodes on 9 out of 10 products. For 7 of these, barcodes were accurately read and information about the product read aloud.	Audio signals (tones and verbal instructions) facilitate blind people to locate the barcode on a product. Signals help the user find the barcode and place the camera at the correct distance. The software runs on the phone so no mobile signal needed. Participants found Handsight at least as good or better than other assistive tech as it was portable and gave access to non-Braille texts and so improved independence. Participants found audio-only feedback helpful for locating lines faster and more accurately and thus increasing reading speed. They used the audio feedback alongside text-to-speech.	Some images were out of focus due to the Nokia N97 phone's slow and erratic camera autofocus mechanism. The phone's computer processing unit was less powerful than a standard desktop computer, which made the system slower to analyse images. The authors argue that these barriers would be reduced in newer and more powerful mobile platforms such as Android and iPhone.
	Stearns et al. [30] Technology: HandSight prototype wearable device	Reading using a hand-mounted wearable device (HandSight).	After a brief training task, participants were asked to read three new articles- one article in each of the three feedback conditions. They were asked questions about ease of use and data about their use of the device was logged. Three participants favoured audio-only feedback, while one preferred a combination of haptic (vibrations) and audio feedback. Participants were also asked to compare Handsight with Braille, screen readers and printed text reading. They found HandSight at least as good or better. They appreciated that it gave them access to non-Braille texts and so improved independence.	Participants found Handsight at least as good or better than other assistive tech as it was portable and gave access to non-Braille texts and so improved independence. Participants found audio-only feedback helpful for locating lines faster and more accurately and thus increasing reading speed. They used the audio feedback alongside text-to-speech.	The authors discuss how the haptic feedback could be improved, e.g. variations in intensity, rhythm, pressure, frequency.
	Fardoun et al. [31]. Technology: prototype smartwatch device	The prototype smartwatch device was designed to help people with Alzheimer's to recognise and remember details about familiar people. The prototype was tested with 41 people with Alzheimer's Disease.	The authors report some usability flaws but do not report how accurately the device recognised people, the impact of using it or participants' views about the device.	Prototype features Cloud architecture to enable data storage and image processing outside of the device, so photo storage is not an issue.	Many participants had visual impairment as well as Alzheimer's and had difficulties reading text on a small screen. The authors plan to address this by creating a text-to-speech feature. Some patients were unable to point the watch at the correct angle to take a photo of someone's face and/or forgot to tap the screen to take the photo. The smartwatch only works with certain Samsung phones. Device can also not be used without an internet connection- during testing some participants were unable to upload photos or download information due to connectivity issues.

(Continued)

Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
	Shilkrot et al. [32] Technology: FingerReader prototype wearable device	Reading a pamphlet, menu, business cards and newspaper articles using FingerReader.	All participants found the business cards and newspaper articles easiest to access and read. They read all the business cards accurately and successfully understood the main points of 4 out of 5 newspaper articles. The pamphlet was also considered easy to access. All found the menu difficult to access due to the multiple column layout. Overall experience of using FingerReader was rated as "mediocre"- they generally found it easy to access text with the device but using it to read was harder and less enjoyable. They found it useful for exploring text but less good for listening to longer sections of text.	Participants generally found it easy to access text with the device, particularly if presented in single columns.	Participants said they would not use the device for longer texts due to fatigue. They found the synthesised voice unpleasant and sometimes difficult to understand. The device had a fixed reading speed - some users read faster than this so had already finished a line while the device was still reading aloud. Participants had different views about preferred feedback methods (e.g. tactile, audio). All participants found the menu difficult to access due to the multiple column layout. The camera does not auto-focus, making it hard to adjust to different finger lengths. The device made errors in recognising characters and words. It needs to be tethered to a companion computation device, e.g. a tablet computer.
	Banf et al. [33] Technology: PictureSensation smartphone app	Understanding an image by touching different parts of it and receiving auditory descriptions using PictureSensation smartphone app.	The blind participant was able to learn to use the device independently- the authors argue that this was due to the design of the user interface and provision of a tutorial and training. The participant successfully provided acceptable interpretations for all images.	PictureSensation can be used in different languages. A voice-guided tutorial has been developed. The participant was able to use the swipe gesture-based user interface design, i.e. there were no on-screen menus or buttons.	Scene labelling and feature extraction were not always precise- the authors anticipate that this will improve in the future, as computer vision technology becomes more advanced.
	Awad et al. [34] Technology: Intelligent Eye smartphone app	Recognising objects, colours and banknotes using a smartphone app (Intelligent Eye).	The application was tested by users with visual impairment who were then asked for feedback. The users gave positive feedback about the app's performance (3.7/5), ease of use (4.1/5), familiarity of interface (4.4), responsiveness (4) and clarity of prompt messages (3.0). The authors report that the app accurately identified objects and banknotes, but no details of testing are reported.	Participants found the Intelligent Eye app easy to use. Descriptions of detected objects and banknotes are read aloud.	Only available on Android.
	Chen et al. [35] Technology: smart glasses for image recognition and reading	Participants completed face recognition, object recognition and text to speech tasks using a wearable smart glass device.	Participants were able to locate people using face recognition. Most participants successfully identified five or more objects. They found the text recognition rate sufficiently high for everyday reading, as long as the font was a standard type. The authors do not report on the accuracy of reading.	Participants reported that they would use the smart glasses at home or at social occasions to find acquaintances. They felt that the recognition time of 2-3s was acceptable.	Two participants found the device uncomfortable to wear due to frequent vibrations when an object was detected - participants would prefer frequency to be reduced or for vibrations to pause while identifying objects. The device struggled to read text in unusual fonts. Several participants found the smart glasses too heavy and would prefer a hand-held to a head-mounted device. Four of the older participants needed longer to learn to use the device than younger ones. All felt that the \$250 dollar cost was acceptable. In order to make the device commercially available, the hardware needs to be upgraded, and better-quality sensors required.

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Table 4. Continued.

Group	Authors, date and technology reviewed	How the technology was used in rehabilitation	Rehabilitation outcomes	Useful features and facilitators	Usability issues and barriers
	Chatpaitoon and Itthipanchpong [36] Technology: CU Eye Reader smartphone app	CU Eye Reader smartphone app uses optical character recognition and text-to-speech to read aloud captured text. Participants were trained to use the app on their smartphone and used it for four weeks.	Participants used the app for an average of 22 min per day. They reported improvements in overall vision-related quality of life with increases on the reading and mobility, but not mental health subscales. 36% of participants expressed being 'very satisfied', and 64% indicated they were 'satisfied' with the app.	Can read English and Thai text.	Only tested on Android smartphones.
4	Dockery and Krzystolik [37] Technology: smartphone apps for low vision	Daily living activities using smartphone apps as low vision aids.	81.8% of respondents reported using an iPhone for low-vision mobile apps. Fourteen apps were identified, with Seeing AI (82%) and Be My Eyes (64%) being the most popular. Their overall ratings were 4.43/5 and 4.75/5 respectively. On average, respondents used four different apps.	Favourite features of the apps were navigation, person-to-person interaction (particularly for Be My Eyes) and help with reading documents. Participants identified useful features of different apps e.g. that Be My Eyes was comprehensive and useful when alone as you can talk to someone who is "right there to help if needed."	Participants identified various issues for different apps, e.g. there was a steep learning curve for some apps, particularly camera functions (e.g. Seeing AI). Participants felt KNFB Reader was not user friendly. Six out of 11 respondents reported that they needed help with navigating apps from family/others in their household. Participants reported that the maximum they would spend as a one-off app purchase was, on average, \$49.50 (range \$0-150). The most commonly used apps were free. Monthly subscription costs were reported as too expensive for one app.
	Sorber et al. [38] Technology: wearable head-mounted devices (Patriot ViewPoint, NuEyes Pro, Orcam, Aira Horizon).	Daily living activities using different wearable head-mounted devices. Patients received training in using their device during inpatient rehabilitation. Device selection took account of the patient's goals.	All four patients achieved goals through using the assistive technology that had not been achieved using conventional optics or traditional non-optical devices. Goals included reading, watching TV, independent travel, home repairs, seeing sporting events, signing documents, seeing faces. The patients were all highly motivated and keen to use the devices in their daily lives. They were able to learn to use the devices quickly and did not report difficulties using them.	Wearable technology was able to overcome reduced contrast sensitivity (which is associated with decreased visual function and orientation/mobility issues) through digital means such as contrast stretching and edge enhancement.	The authors highlight the importance of considering a patient's cognition and physical factors when selecting wearable technology. They discuss factors that may affect usability for different patients, e.g. bulky, portable, cosmetically appealing/inconspicuous. One patient did not find Orcam useful for his travel and shopping goals, e.g. reading distant signs. He found that Seeing AI app was as useful as Orcam for reading and barcode scanning. Patient who used Orcam had a hearing loss and found it difficult to hear device in noisy environments- this was addressed through using Bluetooth headphones.
	Bhagat et al. [39] Technology: Seeing AI, Google Lookout, Envision and Supersense smartphone apps.	Four apps were used for reading, object and currency recognition tasks.	User feedback identified four preferred apps and key parameters for comparing and evaluating them. The researchers then evaluated the four selected apps, identified their strengths and limitations and made recommendations for future improvements. Seeing AI was identified as the most accurate, efficient, usable and accessible app.	Key facilitators for people in developing countries include apps being free, energy efficient and having multi-lingual text recognition.	Key barriers include some apps not working accurately in low lighting conditions, and complex user interfaces

Two articles emphasised the importance of identifying the most suitable device for individual participants depending on their goals and other factors [19,38].

Three studies explored how well different apps or devices performed for different reading material [13,26,28]. van der Aa et al. [26] compared OrCam to three apps (Seeing AI, Envision AI and Lookout) and found participants' reading performance varied depending on the type of reading task, suggesting that certain technologies may be better suited to different forms of reading. For example, OrCam and Seeing AI were more useful for reading a table of contents, whereas the three apps performed better than OrCam for reading a handwritten shopping list, street sign, monetary note and medicine bottle. None of the technologies facilitated reading a TV guide [26]. Granquist et al. [13] reported that both OrCam and Seeing AI were perceived by participants as useful for daily reading activities, and both technologies achieved over 95% accuracy in text recognition. However, participants were able to complete more tasks using OrCam (71%) compared to Seeing AI (55%). In contrast, Seiple et al. [28] compared four technologies, including OrCam and Seeing AI, and reported that Seeing AI had the best performance across a range of reading, searching and identifying tasks, and also had the highest user satisfaction.

Training

Although many studies provided training, only Waisbourd et al.'s [11] study investigated the impact of this. The authors reported that participants' ability to use OrCam improved significantly after training from an experienced instructor, but no further significant improvements were seen after participants had used OrCam for a week, perhaps because their performance was already close to ceiling.

Outcome measures

Two studies reported improvements in vision-related quality of life after using assistive technology to facilitate reading for four weeks, including for a novel app [36]. Waisbourd et al. [11] found that almost three quarters of participants felt their overall vision-related quality of life had improved after learning to use OrCam, as they were able to read books and other documents independently. A limitation of many studies was that rehabilitation outcomes were assessed using unvalidated tests specifically developed for the studies [9].

Useful features, barriers and facilitators to using the technology

In addition to highlighting useful features of apps and devices, the articles also outlined barriers and facilitators to using them (see Table 4).

The four review papers all highlighted a trend towards small, portable and wearable devices and the integration of assistive technology into mainstream devices. According to Souza et al.'s [22] systematic review, this trend is due to miniaturisation of technology, reduction in power requirements and availability of small power sources. Celik and Rohrschneider [19] and Pundlik et al. [21] highlighted the numerous benefits of this, with assistive technology becoming more accessible, affordable, inconspicuous, and socially acceptable, therefore avoiding the potential stigma associated with bespoke specialist assistive technology devices.

The studies also highlighted a variety of usability issues and barriers. One key issue was the availability of apps and devices in languages other than English. Some existing and novel apps, such as PictureSensation [33] were available in different languages. However, the accuracy of the app in different languages was not reported. The high cost of devices and subscriptions can also be a barrier to accessing them in developing countries [39]. The expense of OrCam was highlighted in several studies [10,11,13]. Patel and Parmar [20] also highlighted a lack of knowledge and experience with technology in developing countries such as India, which can be a barrier to using devices. Several articles discussed the pros and cons of different systems and how to increase affordability in developing countries. For example, Chen et al. [35] and Fardoun et al. [31] reported that they chose to reduce costs for users in developing countries by using a cloud server or cloud storage for image processing, because these did not require high performance hardware with large phone storage. However, cloud servers and storage need a strong and consistent internet connection [31].

Usability issues explored in the papers included preferences for different types of feedback and user interface. For example Stearns et al. [30] found that most users preferred audio to haptic (vibrations) feedback, while Banf et al. [33] reported that swipe gestures were easier for people with visual impairment to use than onscreen menus and buttons.

The devices were more usable for some reading tasks than others. Namely, near vision tasks were easier than reading in the distance, and reading text in multiple columns, such as a TV guide or menu, posed particular challenges [26,32]. Unusual fonts and formatting, such as text found on processed food labels, were also a barrier [13,35].

Studies highlighted the importance of considering users' personal preferences and previous technology use when selecting devices. For example, the voiceover feature on a smartphone can be challenging to learn to use [13], but may be useful for people who are already familiar with it. Devices should have a variety of options for personalised feedback (e.g. audio, tactile, combined) as users have different preferences [32].

Some specific technical barriers were identified. For example, OrCam was found to struggle in low lighting conditions [11,13], whereas Seeing AI performed better [13]. High energy consumption was another barrier identified [22]. Some studies reported technical challenges that are likely to be overcome using newer and more powerful devices/mobile platforms. For example, Tekin and Coughlan [29] used a Nokia in their study, but reported that their app would work better on an iPhone or Android smartphone.

Several studies discussed whether age is a potential barrier to successful use of the smart camera technology. For example, in their review article and opinion piece, Celik and Rohrschneider [19] suggested that age may be a barrier because younger people are more likely to own a smartphone or tablet, but they did not refer to any data or case studies that provided evidence that age itself is a barrier to using electronic visual aids. Chen et al. [35] reported that older users needed longer to learn to use a device and that the needs of users of different ages should be taken into account when designing devices. Conversely, Seiple et al. [28], who investigated whether age predicted performance at baseline or change in performance when using smart-camera technology, found no association for any of the four technologies explored. Fardoun et al. [31] developed a smartwatch for people with Alzheimer's disease, many of whom also had visual impairments, and discussed the challenges of designing assistive technology for people with multiple impairments, which are more common as people age.

Discussion

We reviewed 25 articles and abstracts to consider how assistive technology incorporating smart camera features has been used in the rehabilitation for people living with disabilities.

Which types of people living with disabilities was the assistive technology used with?

All but two of the articles focused on assistive technology in relation to visual impairments ($n=23$). However, several articles highlighted that many participants have more than one disability and that this is a key consideration when choosing assistive technology and supporting people with disabilities to use it. For example, Fardoun et al.'s [31] study developed a device to support people with Alzheimer's Disease to recognise and remember information about people they know. They reported that some participants also had visual impairment and that this impacted on their use of the device. Other studies discussed the importance of considering cognition alongside visual impairment [38]. Some authors speculated that assistive technology may be useful for groups other than the ones they were designed for. For example, Shilkrot et al. [32] designed a wearable reading device for congenitally blind people but suggest that it may be useful for people with other types of visual impairment, dyslexia and for supporting early language learning among pre-school children.

The research was mostly small-scale. Among the studies which reported the number of participants, 11.5 was the median. This is in line with other recent research studies exploring the use assistive technology for people with disabilities, with 13 reported to be the median number of participants for studies investigating people with disabilities and older adults [40]. One article [32] discussed the challenges of

recruiting participants to their study. The challenge of recruiting representative users with particular disabilities has been reported more widely in the Human Computer Interaction and accessibility literature, with key barriers including difficulties finding representative users and the users accessing a research setting [41].

How was the smart camera technology used in rehabilitation?

The technology was used on various devices including smartphones, tablets, smart watches, smart glasses and other wearable devices such as FingerReader. The majority of studies focused on assistive technology incorporating text-to-speech and/or object recognition ($n=24$), with reading the most commonly addressed rehabilitation goal. Studies identified different strengths and limitations of the technologies. A clinical case study stressed the importance of considering the client's goals, cognition and physical abilities when selecting suitable assistive technology [38]. Dockery and Krzystolik [37] surveyed visually impaired patients about their use of assistive technology and found that they used on average four different apps, which suggests that they are using different apps for different functions. Indeed, different reading apps/devices were reported to perform better with different reading material [26], which may explain why patients use multiple apps.

What benefits were reported from using assistive technology incorporating smart camera features?

Many studies highlighted the numerous benefits of assistive technology apps which can be used on smartphones, because they are accessible, affordable and inconspicuous. Indeed, even in a study where participants reported positive results with a wearable device, Orcam, only 15% of participants continued rehabilitation using Orcam at the end of the study. Key reasons for participants not continuing to use Orcam were the cost of the device and that they were already using smartphone apps and screen-reading software as low vision aids, which they reverted back to at the end of the study [10].

Improvements in reading were the most commonly reported rehabilitation outcome, with the technology facilitating independence in everyday, functional tasks. However, few studies included a longer-term follow-up to explore whether participants continued to use the technology and find it beneficial. A survey among attendees of a low vision clinic reported that participants were using a variety of different apps in their everyday lives [37], but it is unclear whether this finding would be replicated among people who do not have the support of a low-vision clinic. A review highlighted the limited evidence about the real-world impact of electronic visual aids, but found that user surveys indicated that smartphone apps were increasingly widely used and were more popular than specialist devices [21].

Two studies explored the wider impact of using the technology and reported improvements in vision-related quality of life after using it to facilitate reading for four weeks [11,37]. Being able to read books and other documents independently was cited as a key reason for this [11].

Were any barriers reported to the use of assistive technology incorporating smart camera features?

A wide variety of barriers to accessing and using the technology were reported, ranging from practical factors such as cost and availability in different countries and languages, to usability issues.

Several studies highlighted inequitable access to technology outside of the Global North, due to commercial availability, cost, language and technical know-how [35,36]. Indeed, the World Health Organisation identified that over 2.5 billion people needed assistive technology products, yet only 3% had access in some low-income countries, whereas 90% had access in some high-income countries [3]. They reported that barriers included high costs, low awareness, limited infrastructure, lack of trained personnel, and inadequate product range. Their recommendations for achieving universal access to assistive technology included ensuring products are effective and affordable, involving users and their families across the whole access pathway, raising public awareness and combatting stigma. Researchers have also

highlighted the importance of making cultural adaptations when designing technology, considering not only language, but also aesthetics and social norms, without which technology is more likely to be rejected [42].

Several studies in this review sought to address the gaps in linguistic and commercial availability through developing novel technological solutions to be used in countries such as China [35] and Thailand [36]. These studies reported the early stages of developing new technology, so they did not report on its real-world use.

Barriers related to technical limitations were also reported, such as the technology struggling to read particular text formats or in particular conditions, such as low lighting [9–11,13,24,25,39]. Other barriers related to the user's interaction with the technology, such as people with visual impairment struggling to direct a camera accurately at the text [11,13,23–25].

Several authors discussed candidacy, including whether electronic assistive technology is less suitable for older people, but these studies lacked robust evidence exploring this issue [12,19,35]. This might reflect bias among clinicians who may assume that older people are less interested in or less capable of learning to use assistive technology [43]. There is also a lack of accessibility research generally about older adults, with only 9% of studies between 2011 and 2021 investigating this group [40].

Limitations of evidence base

Among the studies reviewed, there was a lack of user involvement in developing novel technology. User testing typically occurred after development and the questions asked of users were limited and general [34]. Some studies reported carrying out user testing but provided very few details of this [35]. None of the studies reported using Participatory Design [44] or co-design methods [45].

Research has shown that many types of assistive technologies are developed without meaningful user input, resulting in poor usability and low adoption rates [46]. Recommendations for inclusive design include involving users early in the design process to understand real-world needs and contexts and using participatory methods, iterative feedback, and co-design to improve functionality and satisfaction [45].

Accessibility research includes a disproportionate number of studies focusing on visual impairment. Mack et al. [40] reported that in the 10 years between 2011 and 2021, 43% of accessibility research studies focused on people who were blind or had visual impairment. In contrast, people with complex conditions such as cognitive impairment were under-represented.

Future research

Future research should further investigate the usability of assistive devices, identifying factors that facilitate usability for people with specific disabilities and barriers to successful use. Novel technologies should address gaps in currently available assistive technology for different groups and across different linguistic and cultural contexts. Participatory Design and co-design methods should be used to bring together people with lived experience of disability and professionals to develop assistive technology that addresses real-world challenges encountered by people with disabilities [45]. Future research should further explore this technology in relation to non-vision impairments as it may have the potential to be harnessed as a powerful rehabilitation tool for people with other disabilities. It should also investigate and address the needs of people with multiple comorbidities and people with complex conditions. Future research should investigate the real-world impact of using technology and should include robust experimental studies, including RCTs.

Clinical implications

Portable smart camera technology is increasingly accessible and affordable and is often available through mainstream devices such as smartphones. There is evidence of its benefits in rehabilitation of visual impairments, particularly as a reading aid. Its potential use for other disabilities, such as cognitive, language and reading impairments, requires further investigation.

Limitations

One limitation of this scoping review is that the search was restricted to articles written in English, French or German, meaning potentially relevant studies written in other languages may have been excluded. Furthermore, assistive technology research is a rapidly evolving field with varied terminology used across papers, therefore it is possible that relevant articles that used different vocabulary may have been missed. The rapid pace of technological change may also mean that technological features, usability issues, barriers and facilitators reported in this review may have changed since the articles were published, or even by the time an article was published, and may therefore be out of date. For example, many smartphone apps, such as Seeing AI, have updated their object recognition and description features to provide more accurate and detailed descriptions. This review includes studies that were published in the 2010s, which are more likely to be out of date.

Conclusions

Assistive technology incorporating smart camera features has mainly been investigated in relation to visual impairment rehabilitation. Text-to-speech and object recognition have been the most explored features, with less focus on facial recognition and barcode scanning. Reported rehabilitative outcomes included enhanced reading ability and improved daily living skills. However, there were technical limitations, usability issues and high financial costs associated with various devices.

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Author contributions

CRedit: **Anna Caute**: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing; **Leila Mirza**: Investigation, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Bundy Mackintosh**: Conceptualization, Funding acquisition, Project administration, Writing – review & editing; **Reinhold Scherer**: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing; **Victoria Joffe**: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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Notes on contributors

Anna Caute is a Lecturer in Speech and Language Therapy at the School of Health and Social Care, University of Essex. She researches how AAC and assistive technology can enhance communication in aphasia. Her research on assistive technology has investigated the use of e-readers, text-to-speech software and portable smart-camera technologies to facilitate reading. She was Chief Investigator for the NIHR-funded HARP Aphasia Study (Harnessing Portable Smart Camera Technology to Support the Communication Skills of People with Aphasia). This study explored how apps featuring smart-camera technology can be used to enhance communication for people with aphasia who have difficulties with reading and spoken language. Her PhD investigated the benefits of gesture therapy for people

with severe aphasia. Anna is a member of the Royal College of Speech and Language Therapists and the Health & Care Professions Council in the UK.

Leila Mirza is a PhD student at the University of Essex. Her research focuses on loneliness and mental health in LGBT youth. Previously, she worked as a Senior Research Assistant for the NIHR-funded HARP Aphasia Study, an Assistant Psychologist for Talking Therapies and a Team Leader for a supported living service for adults with intellectual disabilities. Her academic background includes a BSc in Psychology and an MSc in Clinical Neuropsychiatry, both of which she completed at King's College London.

Bundy Mackintosh a psychologist and was a public co-applicant on the NIHR-funded HARP Aphasia Study. She has lived experience of aphasia and professional experience in research with over 50 publications. She has worked at the University of Sussex, the MRC Cognition and Brain Sciences at the University of Cambridge, the Open University, and University of East Anglia. She had a stroke in 2009 and retired in 2011, although she continued to work as a researcher at the University of Essex. She gives lectures on anxiety and aphasia to interested people, mainly to Speech and Language Therapists. She is a member of several societies and groups, including the British Psychological Society, the British Aphasiology Society and the Service User Reference Group at the University of Essex.

Reinhold Scherer (PhD) is Head of the School of Computer Science and Electronic Engineering at the University of Essex, UK, and Professor of Brain-Computer Interfaces (BCI) and Neural Engineering. BCIs are systems that translate brain activity into commands for external devices, enabling communication and control without muscle movement—critical for individuals with severe motor impairments. His research spans more than two decades in developing non-implanted BCI and neural interface technologies to support motor rehabilitation, such as aiding stroke recovery, and assistive communication for people with conditions like locked-in syndrome. His work integrates adaptive signal processing and artificial intelligence (AI) techniques that learn from brain patterns to improve accuracy and responsiveness, alongside mobile neuroimaging, to advance user-centred and ethically responsible neurotechnology. Prof. Scherer serves as Vice President of the International BCI Society and is a member of the Centre for Neurotechnology and Law, contributing to interdisciplinary research and policy development.

Victoria Joffe is Professor of Speech and Language Therapy, and Dean of Integrated Health and Care Partnerships at the University of Essex. Her area of clinical and research expertise includes Speech, Language and Communication Needs (SLCN) across the lifespan. Victoria works with health trusts, integrated care systems, education authorities and third sector organisations providing training and consultancy to professionals working with individuals with SLCN. She is co-editor of the journal, *Child Language Teaching and Therapy*, and acts as a speech and language therapy partner for the HCPC. She is chair of the RCSLT's national clinical excellence network for older children and adults with SLCN. Victoria is working on two NIHR-funded research projects looking into a new intervention for children with social communication disorder, and the use of apps to facilitate communication in adults with aphasia (the HARP Aphasia Study). She is also involved in research on stammering, Down Syndrome and dementia, stroke care and provision of services to individuals with SEND.

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Appendix

Data extraction tool

Publication details					Methods						
Title	Authors	Year	Journal	Country	Objective	Type of study/ research design	Data collection	Sample	Number of participants	Age range	Type of rehabilitation/ how tech was used in rehab
Technology					Key findings						
Type of device	Smart camera features used	Rehabilitation outcomes (including gains, limitations and real-world use of tech)	Usability issues	Useful features	Technical limitations	Other barriers	Extra notes				