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Review Article

Assistive technologies and strategies to support the medication management of individuals with hearing and/or visual impairment: A scoping review

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ABSTRACT

Background: Individuals with sensory impairment (visual and/or hearing) experience health inequalities and increased the risk of medication-related iatrogenic disease compared with the general population. Assistive technologies and tailored strategies could support medication management for individuals with sensory impairment to reduce harm and increase the likelihood of therapeutic benefit.
Objective: This scoping review identified assistive technologies and strategies to support medication management of/for people with hearing and/or visual impairment.
Methods: Standard scoping review methodology was used to identify studies that evaluated technologies or strategies designed to support people with sensory impairment with independent medicine management. Electronic databases were searched (MEDLINE, Embase, CINAHL, ACM, Cochrane) from inception to 18/07/22. Independent duplicate screening, selection, and data extraction were undertaken.
Results: Of 1231 publications identified, 18 were included, reporting 17 studies, 16 of which evaluated technologies to assist people with visual impairment and one study to assist people with hearing impairment. The range of technologies and devices included: applications for android phones (n = 6); eyedrop-assistance devices (n = 5); audio-prescription labelling/reading systems (n = 2); touch-to-speech devices (n = 2); continuous glucose monitoring system (n = 1); magnifying technology (n = 1). Ten studies tested early-stage prototypes. Most participants could operate the technologies effectively and deemed them to be useful.
Conclusions: Despite the increasing number of medicine-related assistive technologies, there has been limited empirical evaluation of their effectiveness for supporting individuals with sensory impairment.

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Prototypes appear to be useful for people with visual or hearing impairment, however wider 'real-life' testing is needed to confirm the benefits of these technologies.

Hearing impairment (HI) affects around one in five people (>1.5 billion) globally and is estimated to occur in approximately 30% of people over 60 years old.[1] Visual impairment (VI) affects 2.2 billion people the majority of whom are aged over 50 years.[2] People with sensory impairment are at higher risk of poor health,[3,4] are often marginalized, and face challenges when accessing healthcare information, services, and facilities.[5,6] There is also growing evidence of the challenges that people with sensory impairment experience at all stages of the 'medicines' journey' (Fig. 1) i.e. from the consultation when a medicine is prescribed, to ordering, obtaining, and storing medicine, its administration, and disposal.[7–9]

Individuals with sensory impairment require person-centered consultations. People with HI often experience communication challenges during consultations and at the point of ordering and obtaining their medicines. Failure to hear the full instructions about medication storage or administration, as well as limited ability to seek information from healthcare providers (HCPs)[10,11,12] has resulted in medication errors, e.g. over-dosing.[13]

In addition, failure to accommodate the challenges associated with medicine management by people with VI during consultations can result in the prescription of formulations or devices that are unsuitable for the patient's needs or preferences. People with VI are more likely to rely on help, usually from family members, to obtain, store, and administer their medication.[14] People with VI often struggle with recognizing and distinguishing between medicines, have difficulty due to changes in medication and packaging, and the identification of medicine expiration dates.[11,15–19] Liquid formulations can be difficult to measure resulting in spillage and incorrect dosing.[17,18,20,21] Individuals may resort to drinking the medicine directly from the bottle, thus consuming an unknown dosage.[17,18,21] Written information, e.g. medicine labels, package inserts, is often illegible for people with VI.[20–22] These challenges can lead to errors of administration and omission,[17,18,22] additional costs incurred for more frequent refills,[22] increased adverse events, and hospital admission.[23]

Different models and guidelines exist for prescribing, and in the UK, the Royal Pharmaceutical Society developed national good practice guidance for medicines optimisation[24] defined as *"a patient-focused approach to getting the best from investment in and use of medicines"*. The guidance is based on four principles including understanding the patient's experience, evidence-based choice of medicines, ensuring medication use is as safe as possible, and embedding medicines optimization in routine practice.

Accessibility standards were introduced in 2017 to address information and communication needs within healthcare.[25] In addition, assistive technologies and strategies are being developed that have the potential to improve safe, person-centred, and effective use of medicines by people with sensory impairment. Assistive technology is the application of organized knowledge and skills related to assistive products, including systems and services.[26] Assistive products and systems range from 'low' to 'high-tech' solutions and include textured (tactile) labels to speech-generating devices and applications.[27] Concerns remain about the cost and lack of universal availability of such products and strategies, and there is limited evidence regarding their role in medication management for people with sensory impairment.[28,29]

The aim of this scoping review was to identify empirical evaluations of assistive technologies and strategies which could be applied to support medication management for people with sensory impairment.

Review question

What assistive technologies and strategies have been evaluated to optimize the safe and effective use of medicines for people with hearing and/or VI?

How the technologies and/or strategies were evaluated in terms of research design and outcome measures?

Methods

This scoping review was conducted and reported in accordance with the Joanna Briggs' Institute methodology for scoping reviews[30] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR).[31] The protocol was registered in advance on the Open Science Framework.[32]

Inclusion and exclusion criteria

Participants

This review considered studies that evaluated any type of technology or strategy designed to support individuals with medication management (i.e. ordering, storage, or administration). Technology could include, but was not limited to, devices or mobile applications for smart phones/tablets.

Studies were included if they involved participants who were community-dwelling people (≥16 years) with sensory impairment who use medication regularly. All levels of impairment severity were included, i.e. partial to full impairment.

Studies were excluded if they involved children or individuals who resided in residential or nursing care homes and evaluated technology involved in patient rehabilitation or medicines administered by others. Unpublished and grey literature was excluded.

Experimental and quasi-experimental study designs including randomized controlled trials (RCTs), non-RCTs, before and after studies, and interrupted time-series studies were included. Studies that used qualitative methods, e.g. ethnography, action research, and usability testing were included if empirical data were presented.

Fig. 1. The medicines' journey.

Search strategy

The search strategy was constructed using a combination of index terms and text words (Appendix I). Subject librarians from the research teams' universities advised on and reviewed the search terms and strategies used. The search strategy was adapted for each of the five electronic databases searched: MEDLINE; Embase; CINAHL; ACM (Association for Computing Machinery) Digital Library; the Cochrane Library and the platforms used, e.g. OVID. All databases were searched from inception to 18/07/22. The reference lists of all included studies were screened for additional studies. The review was not limited by language of publication or geographical region.

Study/source of evidence selection

The search results were uploaded into Covidence[33] systematic review software and duplicates removed. Independent, duplicate screening was undertaken for the titles and abstracts (PF, KB) and for the assessment of full texts retrieved (LC, SJ). Reasons for exclusion were recorded. Disagreements were resolved through discussion or with the involvement of an additional reviewer.

Data extraction and analysis

Independent, duplicate data extraction of included studies was undertaken (LC, SK) using a bespoke data extraction tool (Appendix 2). The data extracted included methodological and participant characteristics as well as specific details about the participants, concept, context, study methods and key findings relevant to the review questions. Due to the heterogeneity of the included studies, a narrative analysis was conducted. No formal quality assessment was conducted.[30]

Critical appraisal

Duplicate, independent critical appraisal of the included studies was undertaken using the Mixed Methods Appraisal Tool (MMAT).[34]

Results

Following the removal of duplicates, a total of 1218 citations were identified from the electronic database searches, and 13 additional studies were identified by searching citations and reference lists. In total, 141 full text articles were retrieved of which 18 were included, reporting 17 studies. Fig. 2 details the study selection flowchart presented according to the PRISMA-ScR.[31]

Description of studies

The characteristics of the included studies are presented in Tables 1 and 2. All included studies evaluated technologies; none evaluated strategies. Three studies were conducted in Canada[35–37] and Thailand,[38–41] two each in the United States of America (USA)[42,43] and Finland[44,45] with the remaining studies conducted in the United Kingdom (UK),[46] Brazil[47] South Africa,[48] Columbia,[49] Switzerland,[50] Netherlands[51], and Iran.[52] Study designs were four studies based on co-design principles,[39,48–50] three RCTs,[40,42,51] two cohort studies,[38,47] two pilot studies,[35,44] and one each of goal-directed design,[52] prospective observational study,[37] case-control study,[43] case report,[46] comparison study,[36] and interviews and usability testing.[45]

Sample sizes varied substantially from one participant in a case study[50] up to 588 participants in the largest study[51] (median = 40). One study included people with HI,[48] whilst the remainder included people with VI. Some devices could be adjusted (e.g. volume) to assist those with dual impairment.

Critical appraisal

The completeness and transparency of reporting the included studies varied substantially and some items of the MMAT could not be scored due to lack of information (Table 3). The MMAT was not completed for two studies [46,52] due to the lack of clear research questions. There was substantial variation in the methodological quality of the included studies and only three studies were deemed to have achieved all quality markers for their design, one of which was a randomized study[40] and the other two were quantitative, non-randomized studies.[37,43]

Assistive technologies and strategies

Devices

All devices were designed to support people with medicine administration (Table 2). Five studies assessed the effect of devices to assist people with eye drop administration.[37,41,42,47,51] Four studies evaluated communication devices—two of which investigated low-cost audio-prescription labelling (APL) systems,[38,43] one reported on the evaluation of BlindNFC,[45] a prototype near field communication system and the other developed and tested a prototype touch-to-speech user interface. One study compared the Apple iPad Air (Apple Inc, Cupertino, CA) using the SuperVision + Magnifier app with the Optelec Compact 5HD video magnifier (Optelec, Longueuil, Canada) for use as a spot-reading magnifyier.[36] One case study involving a patient with Type 1 diabetes, who had been blind since childhood, reported the effect of 'Dexcom', a real-time continuous glucose monitoring system that transmits data to the patient's smart phone about hypoglycaemic episodes.

Applications (apps)

Six studies evaluated apps (Table 3), five targeted people with sensory impairment (SignSupport, Farmaceutic-App, MyPills, MedVision, Ru Tan Ya and one (ClereMed) was developed for use by pharmacists to identify patients who had difficulty reading prescription labels and provide realistic, individualized recommendations to improve the legibility of labels.[35,39,48-50,52] Five of the six apps were developed for smart phones and one for Apple iPad. One app (SignSupport[48]) was aligned with the ordering and obtaining phases of the medicines' journey and one (Ru Tan Ya) with storage and administration. All others were designed to improve safety and efficacy of medicines administration.

Ten studies involved testing the technology at an early prototype stage in a controlled environment for a one-off or short period of time rather than a natural setting, e.g. at home and for a longer period of time.[35,36,38,39,44,45,48-50,52] Outcome measures in these studies included functional assessment, time-to-complete tasks, and user-rated ease of use.

Findings related to clinical outcome or usability

The ScripTalk Study[43] compared the number of hospitalizations of veterans enrolled in the ScripTalk programme, who used at least one medication with a low therapeutic index (defined as high risk), with a control sample of high-risk people with typical vision.[43] The average number of hospitalizations was 2.56 with ScripTalk only, 1.46 with ScripTalk plus a pillbox, and 1.7 with the control group; the difference was not statistically significant.

The Dexcon[46] case study measured glycaemic control and glucose variability in one individual.[46] The device enabled the user to accurately monitor his blood glucose levels without fingerstick testing. A progressive decrease in the patient's HbA1c was shown, as well as improved glycemic control and increased confidence to treat mild hypoglycaemia, all of which led to improved self-

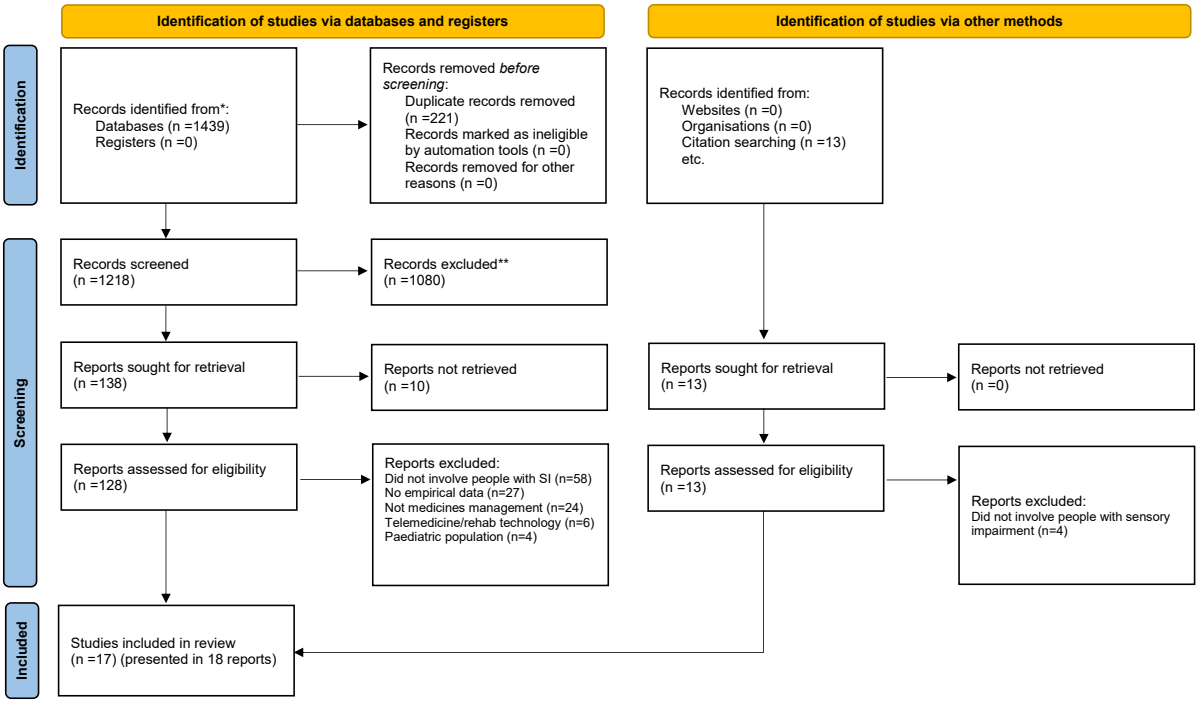

Fig. 2. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources. *From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/.

reported quality of life.

Five studies evaluated devices for eyedrop administration, (Upright eyedrop bottle, Eyedrop®, Eye Drop Guide, Mirror Had Aid, TravAlert®).[37,41,42,47,51] Three studies evaluated the effect of devices in terms of administration time. One device decreased administration time,[42] one increased administration time,[40] and one had no effect on administration duration.[37] Devices were shown to reduce bottle tip contamination in three studies,[37,40,42] but did not improve accuracy of drop instillation[37,42] or intraocular pressure.[47,51] Three studies evaluated participant satisfaction with the device. The Eyedrop® was rated highly,[47] whereas participants were not satisfied with the TravAlert® and were less adherent to treatment[51] and the participants in the study that evaluated the Eye Drop Guide preferred their usual method of instillation.[41]

The remaining studies reported findings related to the usability of the technology. Usability was evaluated by patients,[35,36,38,39,44,45,48-50,52] people without impairment,[35,50] and senior pharmacy students.[48] All studies reported positive aspects of the technology evaluated. No differences were reported in the ability of participants to complete tasks using the Optelec or the iPAD.[36] Most (96%, n = 48) users with VI agreed that the low cost APL machine was easy to use and 85% agreed that the audio-labelling for the speaker was sufficiently clear; however, 20% suggested that the audio-function should be louder to enable use in patients with dual visual and HI.[38]

Participants who tested the HearMe medication management service reported it easy to learn and use regardless of previous computer skills.[44] Personal and contextual barriers were identified, however, such as participants not considering themselves to be in the potential user group or having an established method of managing medications, sometimes with the help of others. Users were able to complete three out of four tasks using BlindNFC, and the majority (>50%) preferred the computerized voice to the natural voice.[45] Some participants (29%, n = 10) were unwilling or unable to complete the tag writing task as they reported difficulty in finding the recording button.[45]

Senior pharmacy students reported that SignSupport[48] decreased dispensing time (9.6–4.23 min), was easy to use, and improved dispensing to Deaf patients. Deaf users also reported SignSupport as easy to use and stated they would use it in real life but were concerned that pharmacists would not accept the software.

Blind users and people with low vision were able to, respectively, download and start the FarmaceuticApp in a mean time of 3 min and 2 min, capture bar codes in five and 2 min, voice command in three and 2 min, and text in three and 2 min.[49] Users scored the app between 4 and 5 (good/very good) and all (100%) stated that they would use the app.

The MyPills app was immediately understood by users who described it as 'clear and understandable'.[50] Scanning of the drug package and the online audio link to the package insert was very helpful and all testers would use the app in everyday life.[50]

MedVision was described as useable; however, users thought ease of use would be increased if the system dimensions were reduced making the medication box more portable.[52] Users believed the system would improve medication adherence in this population.

Ru Tan Ya users reported the top function was the individual drug database followed by the map function and the medication adherence timer.[39] Users reported that too many fields were difficult to input and aid from pharmacist or another sighted individual may be required; however, the majority of participants agreed that the application could facilitate better self-healthcare.

The ClereMed App was assessed using the Systems Usability Score and achieved a score of 76/100.[35] Most (84%) participants agreed that the App was easy to use, with participants who owned

Table 1
Studies that evaluated devices to assist people with sensory impairment* with medication management (n = 11) (*studies included participants with visual impairment only).

Study ID, Year of Publication, Country	Study design	Sample demographics	Intervention	Outcome measures	Key Findings/Results	Costs
Beckers 2013[1] **Netherlands**	Randomized controlled trial: 4 study arms 1) Use of the TravAlert dosing aid, (2) Use of the dosing aid with the TravAlert-Eyot drop guider, (3) Use of the dosing aid together with patient education and (4) Use of the dosing aid and drop guider together with patient education	n = 588 outpatients with a diagnosis of POAG or OHT and a minimum age of 18 years. Mean age 66.3 ± 10.6 years (Range 23–92 years) 54% men	**TravAlert.** Monitoring device for the use of Travoprost 0.004%. Drop guider (TravAlert-Eyot) correct instillation of eye drops.	Medication use; Adherence; Patient satisfaction	Mean intra-ocular pressure (IOP) declined from baseline to 6 months in all groups - NS. 91% mean overall adherence rate over six months - more adherent patients in study arm 4. Most non-adherent patients in arm 2. SS difference between patients who used drop guider and those who did not - those using drop guider were less adherent. Patients were generally satisfied or even very satisfied with their dosing aid.	
Bishop 2021[2] **UK**	Case report	n = 1 56-year-old male with type 1 diabetes and blind since childhood	**Dexcom** real-time continuous glucose monitor (CGM) system that transmits interstitial glucose level data to patient's smart device (Apple iPhone with audio feedback function)	Glycaemic control and glucose variability.	HbA1c results checked approximately six-monthly have progressively decreased. Patient experienced improvement in glycaemic control and glucose variability. Increased quality of life and increased confidence to treat mild hypoglycaemic without large quantities of carbohydrate, therefore reduction in rebound hyperglycaemia.	Not reported
Davies 2016[3] **United States**	Randomized controlled trial.	40 patients (60% female, average age 72.4) attending glaucoma clinic who had self-reported trouble instilling their eye drops	Upright eyedrop bottle (UEB). Crossover trial comparing UEB with normal bottle.	Medication use; Time taken to instil eye drop, excess number of drops instilled, contamination of bottle tip	Accuracy of drop instillation - no statistically significant (SS) difference. Time taken to instil drops with the UEB was significantly shorter than conventional bottle. Reduced excess with the UEB. Tip contamination - UEB none. Conventional bottle 16/20 patients.	Not reported
Ervasti 2011[4] **Finland and Spain**	Interviews and useability tests	39 Older people with varying degrees of visual impairment (Age range 34–92)	**BlindNFC.** Near Field Communication (NFC), very short-range wireless technology that allows electronic devices to exchange data upon touching. Special presentation of Radio Frequency Identification (RFID) technology.	Useability tasks. 1.Location of NFC tags on medicine packages. 2.Reading the tag with the NFC device. 3.Preference for synthesised versus human voice. 4.Tag writing using voice messages	Average times: task 1 = 13.1s. All users able to complete the task. Task 2 = 19.6s. Some had difficulty related to find the right angle or appropriate touching duration. Task 3 = 3.7s - one user could not complete the task. >50% of participants preferred the computerised voice due to the clarity and lack of background noise. Task 4 = 22.6s but 10/34 users were not able or willing to complete the task - difficulty in finding recording button on the device. High degree of satisfaction in the use of the device reported.	Not reported
Harjumaa 2011[5] **Finland**	Pilot study evaluation	8 older adults (age range 69–89, 4 female) with VI	**HearMe.** A medication management service with a touch to speech user interface.	How well users are able to adopt and use the service. How useful do the users find the service concept and possible barriers to technology adoption.	All users found the service concept easy to comprehend, learn and use the service for identifying their medication and internalize their personal medication information, regardless of their prior computer skills. Setup very reliable, and users did not require any technical support during the study. Usability problems were identified: use of contextual cues, order of information provided to the user, clarity and speed of the speech synthesizer and NFC tags. Barriers 1. Participants in pilot might not consider themselves to be included in the potential user group of the service. 2. Participants might not have perceived actual problems in medication management. 3. Participants established their own methods for medication management, solution should offer added value. 4. Social environment	Not reported

(*continued on next page*)

Table 1 (*continued*)

Study ID, Year of Publication, Country	Study design	Sample demographics	Intervention	Outcome measures	Key Findings/Results	Costs
					- preferred the help of other people to that of technology. 5. Experimental setup not convenient. 6. Fear of showing vulnerability.	
Junqueira 2015[6] **Brazil**	Cohort study	32 Participants 44% with glaucoma and healthy people (72% female. Average age 42.3)	**Eyedrop.** Device to improve efficacy and safety of eye drop instillation. Patients used the device on one randomly selected eye.	Medication use. Intraocular pressure	No statistically significant difference in mean IOP variation when comparing the eye on which the applicator was used (-3.9 ± 2.9 mmHg) and the eye on which traditional instillation was used (-3.3 ± 2.6 mmHg; $P = 0.36$). The subjective rating of instillation was significantly higher with the use of applicator (VAS $= 7.6 \pm 1.6$) than without it (VAS $= 6.2 \pm 1.8$; $P < 0.01$).	Not reported
Lertwiriyaprapa 2015[7] **Thailand**	Cohort study	50 people (68% female) with visual impairment. Age ranged from <25 years to >80 years, 17/50 (34%) used medicine daily	An Audio Prescription Labelling (APL) 2 part system: software to prepare RFID label affixed to medicine container and APL machine to read the Radio Frequency Identification (RFID) tag	Ease of use of new technology	96% agreed the APL machine was easy to use. 85% of the blind and elderly agreed audio labelling from the speaker of the APL machine was clear enough. Conflict in the opinion between blind and elderly regarding convenient to carry and the size of the APL machine.	US$100 or less. Mass production of RFID reader components would reduce the cost to less than US$30
Sakiyalak 2014/17/ 2020 **Thailand**	Randomised controlled study	n = 59 (Group1 n = 30, group II n = 29) patients with chronic glaucoma	**Eye drop guide** (EDG) Crossover study comparing EDG with traditional technique for eye drop installation.	Medication use; correct instillation of eye drops. Time taken, instillation of only one drop, avoidance of bottle contamination	Eye drops instillation success - EDG technique 61%. Traditional technique 66.1% - NS ($p = 0.60$). 15% and 8% unable to instil one whole drop into the eye. Bottle tip contamination using traditional technique n = 13. Time taken to instil eyedrops with the EDG was significantly longer than with the traditional technique. EDG was not more effective than the traditional technique given careful instruction. Follow-up EDG use: 19.3% always, 35.1% regularly, 45.6% never	Not reported
Spektor 2015[8] **United States**	Case control study	84 VI veterans (4% female). Aged 49−97 enrolled into the ScriptTalk program. Used at least one medication with a low therapeutic index - determined as high-risk, compared with 16 (all male) adults (aged 42−83) with typical vision who fit the high-risk criteria	**ScripTalk** - A thin microchip is embedded onto a prescription bottle, storing prescription label and leaflet data. Uses RFID text-to-speech technology, all the information embedded within the microchip prescription label is audibly read aloud to the individual.	Hospitalisation rate	Average rate of hospitalisation per participant: ScripTalk cohort 2.56 Control group 1.70. NS ($P > 0.08$). Average number of hospitalizations among ScripTalk + pillbox users was 1.46; while the average number for ScripTalk only users was 2.14. The degree of vision loss was the strongest risk factor for increased hospital admissions among the population who used ScripTalk.	Free to users - cost for pharmacies
Strungaru 2014[9] **Canada**	Prospective, observational study	n = 30 patients with glaucoma who had used glaucoma eye-drops for at least 6 months.	**Mirror hat aid** -The device consists of a concave magnifying mirror attached to a brimmed baseball-style cap	Medication use, technique, time taken, accuracy and error	Bottle tip contamination: with device 13.3%, Without 35% SS ($P = 0.02$). Drop could be seen: with device 86.7%, Without 40% SS ($P < 0.001$). Time taken: NS differences. Number of eye drops dispensed - with device 1.3 ± 0.6 with device, without 1.2 ± 0.5.50% liked device.	Can$20
Wittich 2018[10] **Canada**	Comparison study	60 adults (57% female) with low vision (age range, 19−97 years) mean visual acuity, 20/136	Comparison of Optelec Compact 5 HD portable video magnifier and the Apple iPad Air tablet computer using the SuperVision + Magnifier app from Massachusetts Eye and Ear Infirmary	Performance speed using a short language and reading questionnaire. Find the name of the medication, expiration date (eye drops 1 and 2). Modified version of the Quebec User Evaluation of Satisfaction with assistive Technology	Performance speed indicated that easier tasks were completed faster; NS difference between two devices. The highest satisfaction scores for both devices identical: dimensions, ease of use, and effectiveness. Preference 25 for iPad, 33 for portable closed-circuit television, and 2 undecided. There were NS differences in the ability to complete the tasks between each device or because of the differences in level of difficult.	iPad Air Can$429 Optelec Compact 5HD Can$950

EDG: Eye Drop Guide HbA1c: Glycated haemoglobin IOP: Intraocular pressure NS: Not statistically significant n: number POAG: Primary open angle glaucoma OHT: Ocular hypertension SS: Statistically significant UEB: Upright Eyedrop Bottle VAS: Visual Analogue Scale.

a computer or touchscreen device reporting greater usability than those who did not own a computer or device.

Findings related to accuracy

Studies reporting the accuracy of eye drop instillation using a device reported no statistically significant difference.[40,42]

ClereMed[35] correctly identified 71% of participants who had functional VI and 86% who had healthy functional vision.

SignSupport[48] contained 162 instruction videos for pharmacy dispensing. However, 35 of these were found to be undecipherable, ambiguous, or the semantics did not match the conversation script.

There were some usability difficulties with the Ru Tan Ya app due to bugs or doubt of visual representation.[39]

Cost-related outcomes

Limited economic data were presented. Three studies reported costs related to the purchase of the system or the development of a new technology. The iPAD Air cost was Can$429 (£282) compared with the Optelec Compact 5HD cost of Can$950 (£625).[36] The production cost of the APL system was estimated at US$30 (£27). The Mirror Hat device cost Can$20 (£13) to produce.[37] In addition, the evaluation of ScripTalk was based on the free provision of the system to users and the loan of equipment by manufacturer (Envision).

End-user involvement

Six studies included care providers or end users early in the development phase.[39,42,44,45,48,49] The first employed a user-centered design process and interviewed 48 people with low vision or blindness to identify user needs and barriers for the appropriate use of medications.[49] The second consisted of a five-step user-centered approach involving 60 members of the Vision Disability Association.[39] The third study incorporated Deaf participants in the multi-disciplinary team from design to development and verification of the app.[48] Deaf team members decided what the project was and how they would like to use it. Two studies were described as using a co-design process that involved elderly care personnel, pharmacy professionals, and representatives from associates for blind and older people with VI.[44,45] Davis et al.[42] refined the prototype design in an iterative process using feedback from a small cohort of patients.

One study design was described as "goal directed";[52] however, the designers defined a few personas gathered from literature searches to identify their goals rather than end users.

Discussion

The review included 18 studies that reported empirical testing of 17 assistive technologies related to medication management. The diversity in the range of countries conducting this research suggests a global interest in improving medicines management for people with sensory impairment. Of the 17 technologies reported, four are currently available to the public: ScripTalk (from US pharmacies); Dexcom; TravAlert; and Ru Tan Ya (downloaded in Thai-only).

The findings of this review highlight a lack of empirical evidence for the long-term benefits of any technology included. Several studies evaluated the effect of the device/technology on safety; however, few studies evaluated the effect of the device/technology on clinical outcomes (effectiveness).

One aim of using technology to facilitate medicine use should be to increase patient safety through ease of use; therefore, outcome measures should explore the impact of technologies on clinical outcomes related to medicines management. In this review, one study measured the rate of hospitalisation,[43] another assessed the impact on stability of blood glucose.[46] One study investigating a device to assist with eye drop instillation measured intraocular pressure.[47] In eight studies, the outcome measures were usability and acceptability. There was also a tendency for studies to focus on administering medicines; however, people with sensory impairment often face challenges throughout all stages of the medicines' journey.[9] There is need, therefore, for empirical evaluations of the long-term impact of devices and apps used by people with sensory impairment throughout all stages of the medicines' journey.

The World Health Organization Global Disability Action Plan (2014–2021) called for end-users to be actively included in disability-related research.[53] Only six studies in this review included end-users or professionals involved in their care in identifying patient needs to design technology.[39,42,44,45,48,49] The majority of studies sought feedback from end-users on the 'finished' product rather than involving the users in the development of the product. A person-centered approach would have resulted in products designed 'with' them rather than 'for' them.[54]

Co-design is a participatory approach where the end-user is involved as a partner in the process to harness *"the creativity of designers and people not trained in design working together in the design development process"*.[55] In qualitative interviews involving co-design method experts and mobile health (mHealth) system developers, it was noted that key stakeholders such as the end-users should be involved from the start to help overcome the common challenges faced in designing these devices/apps.[56] As such, beyond end-user testing for usability, researchers have suggested that end-users should also be involved in the development stage of the app/technology to ensure it meets their actual needs, which will then ensure uptake of the device/service.[54,57,58] Indeed, people with sensory impairment are ideally placed to identify their needs and challenges related to medicines management, as well as their wider healthcare needs. Future research based on co-design principles from the outset will strengthen the relevance and acceptability of designed products to the target population.

Concerns about the reluctance of HCPs to adopt these technologies highlighted in the SignSupport study could stem from patients' own poor experience with HCPs with regard to their sensory impairment.[48] A study in South Korea reported that two thirds of patients with VI stated that pharmacists had not modified their counselling to accommodate their sensory impairment.[19] Patients have reported discrimination by HCPs, e.g. resulting in being marginalized and treated last when their impairments were disclosed.[10,17]

Studies have also reported that while HCPs acknowledge the benefits of some medicine-related technologies, concerns, and challenges have been highlighted including difficulty in using the devices, security concerns associated with the safety of patient data, and the reliability/credibility of the content of information provided.[59,60,61,62] These factors might also impact the uptake of such technologies by HCPs.

End-users in the HearMe[44] and BlindNFC[45] studies stated that they would not use the device, either preferring to rely on their carers/family members to help with their medicines or preferring to use measures they have long used.[44,45] This is similar to other studies where despite perceiving the benefits of a technology/device, long-term patients were either more comfortable with 'traditional' methods for using their medicines or had developed their own strategies for their medicine regimen,[21,62,63] for example, the use of low-tech devices, e.g. rubber bands, tactile markers.[17,21,22]

The costs of assistive technologies can be prohibitive and has been identified by people with sensory impairment as a major

Table 2
Studies that evaluated mobile devices to assist people with visual or hearing impairment with medication management (n = 6).

Study ID	Study design	Sample demographics	Impairment	Intervention	Outcome measures	Key Findings/Results	Costs
Motlhabi 2013[1] **South Africa**	Community based co-design.	Deaf people (n = 8) and senior pharmacy students (n = 8).	Hearing	**SignSupport**. Sign language videos are pre-loaded into an Android phone memory card. Two interface screens, one each for the pharmacist and the Deaf user.	Usability	Pharmacists reported that the system was easy to use to dispense medicine to a Deaf patient. Average dispensing time reduced using Sign-Support (4:23 min compared with 9.55 min). Deaf users reported to SignSupport easy to use for collecting medicine.	Not reported. Authors suggest patients could borrow smart phone with SignSupport from Dr. surgery.
Madrigal-Cadavid 2020[2] **Columbia**	User-centred design process - including cross sectional study and usability test.	48 people (48% female), 54% low vision, 46% blindness, aged 18–60 years who used 1–9 medications daily interviewed. 20 people (10 with blindness and 10 with low vision) tested the app.	Visual	**FarmaceuticApp.** A mobile app based on user requirements for access to drug information.	Identification of needs and barriers. Useability: participants were timed performing assigned tasks.	Median Scores (time) recorded for blind users/people with low vision as follows: Download app; 3/2 min, Start-settings; 2/2 min, Capture of barcode; 5/2 min, Voice command; 3/2 min, Text; 3/2 min Users scored FarmaceuticApp between 4 and 5 (good and very good) and 100% of users would use it	Free to use
Nedovic 2019[3] **Switzerland**	Concept and app development and usability test	2 blind persons and 4 normal sighted persons aged 30-70	Visual	**MyPills**. Smartphone app to help visually impaired people with medication management. Functionalities: Scanning of Global Trade Item Number (GTIN) on the medication package. Voice output of medication name and intake schema. Voice output of the package leaflet.	Focus group discussions. Testing pre-recorded sign language videos, stored on a phone's memory card, for correctness.	MyPills App easy to understand and concept very useful. The blind people found scanning of the drug package very helpful. Would prefer if the camera has a larger scatter so that scanning is facilitated. Online link to the package insert and the voice output of the package insert very helpful.	Not reported
Nimmolrat 2021[4] **Thailand**	User-centred approach that consisted of 5 steps	60 (47% female) members of the Vision Disability Association who were more than 90% vision impaired (93.33% blind and 6.67% low vision) and owned a smartphone	Visual	**Ru Tan Ya**. Mobile health application that gives equal opportunity for visually-impaired to access health information. Database contains monographs of 616 medicines including indication of the active ingredient(s), dosage and administration, supply, storage and handling, side effects, drug interactions, as well as warnings and precautions.	Usability of 5 functions: searching for medicines information, a medicines adherence and timer, map function (pharmacies), a personal medicines history record, and a function to create personal medicines database.	Function rating: individual drug database function top followed by the map, medication adherence timer. Usability difficulties were found 70 times (56 times due to bugs and 52 times due to doubt of visual representation). Satisfaction: majority of participants agreed app could facilitate better self-healthcare and be a more efficient tool to search for primary-care treatment information. Some functions, such as the personal medicine database, may be suitable for use with the aid of pharmacists or other sighted individuals rather than visually impaired users themselves. too many fields are difficult to input, despite the use of voiceover	Free to use
Grindrod 2014[5] **Canada**	Pilot study	47 participants (60% female). Age range 55–93 years, 15% functional visual impairment and 62% had mild cognitive impairment. 77% reported at least one condition that could affect ability to see and/or understand prescription labels	Visual	**ClereMed**. Mobile app on an iPad to help pharmacists identify and support adult patients over age 55 who may have difficulty reading or understanding prescription labelling.	Participants were handed a pill bottle with instructions written in Arial, 9-point font (eg, "Take ONE tablet THREE times daily") and asked to place the pills into a pillbox in accordance with the instructions	Systems Usability Scale (SUS) was 76/100.84% agreed app was easy to use. Participants with VI noted that the yellow colour in the simulation was hard to see. ClereMed correctly identified 71% of participants with functional VI and 86% with healthy, vision. Participants found the app to be simple and thought it could quickly identify patients with visual impairment within a pharmacy.	Not given
Farhadyar 2018[6] **Iran**	Goal-directed design.	3 Visually impaired users	Visual	**MedVision.** Three part system android mobile device.1) Radio frequency identification (RFID) device for identification of medications, 2) mobile app for management of the medications and reminders 3)Vibrating medication box for locating the tablets	Functional assessment	Participants stated the system is useable for people with this disability. A decrease in system dimensions could make it easier to use and increase its portability. Belief that this system can improve the medication adherence and independence.	Not reported

Legend: Studies in this table are presented by type of sensory impairment.

Table 3
Critical Appraisal of Included Studies using the Mixed Methods Appraisal Tool.[1]

MMAT	Item	Harjumaa 2011 [2]	Nedovic 2019 [3]	Sakiyalak 2014 (2017) [4]	Beckers 2012 [5]	Junqueira 2015 [6]	Spektor 2015 [7]	Stungaru 2014 [8]	Witticch 2018 [9]	Madrigal-Cadavid 2020 [10]	Lertwiriyaprapa 2015 [11]	Nimmolrat 2021 [12]	Sakiyalak 2020 [13]	Grindrod 2014 [14]	Davies 2016 [15]	Ervasti 2011 [16]	Motlhabi 2013 [17]	Bishop 2021 [18]	Farhadyar 2018 [19]
S1	Are there clear research questions?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
S2	Do the collected data allow to address the research questions?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
1.1	Is the qualitative approach appropriate to answer the research question?	Y	Y																
1.2	Are the qualitative data collection methods adequate to address the research question?	Y	Y																
1.3	Are the findings adequately derived from the data?	N	N																
1.4	Is the interpretation of results sufficiently substantiated by data?	Y	C																
1.5	Is there coherence between qualitative data sources,	Y	N																
	collection, analysis and interpretation?																		
2.1	Is randomization appropriately performed?			Y	C	C													
2.2	Is randomization appropriately performed?			Y	Y	C													
2.3	Are there complete outcome data?			Y	C	Y													
2.4	Are outcome assessors blinded to the intervention provided?			Y	Y	Y													
2.5	Did the participants adhere to the assigned intervention?			Y	C	C													
3.1	Are the participants representative of the target population?						Y	Y	C	Y	Y								
3.2	Are measurements appropriate regarding both the outcome and intervention (or exposure)?						Y	Y	Y	Y	N								
3.3	Are there complete outcome data?						Y	Y	Y	C	Y								
3.4	Are the confounders accounted for in the design and analysis?						Y	Y	C	N	N								
3.5	During the study period, is the intervention						Y	Y	Y	Y	Y								
	administered (or exposure occurred) as intended?																		
4.1	Is the sampling strategy relevant to address the research question?											C	C	Y	N				
4.2	Is the sample representative of the target population?											Y	C	N	Y				
4.3	Are the measurements appropriate?											Y	Y	Y	Y				
4.4	Is the risk of nonresponse bias low?											Y	Y	C	N				
4.5	Is the statistical analysis appropriate to answer the research question?											Y	Y	Y	Y				
5.1	Is there an adequate rationale for using a mixed methods design to address the research question?															N	N		
5.2	Are the different components of the study effectively integrated to answer the research question?															Y	N		
5.3	Are the outputs of the integration of qualitative and															Y	N		
	quantitative components adequately interpreted?																		
5.4	Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?															N	N		
5.5	Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?															N	N		

Y: Yes N:No C: Can't tell N/A: Not applicable

influence on their decision to use them or not.[23,22,21] Only three studies provided cost data .[36,37,43]

Older people have highlighted factors that limit the utility of assistive devices including technical difficulties,[62] complexity, e.g. mHealth apps,[63] and their psychomotor and cognitive limitations.[64] As such, it is imperative that the design and testing of assistive technologies to support safe and effective medicine management should be undertaken in collaboration with the intended end-users.

This review did not focus specifically on older people's use of technology; however, this group is among the most affected by HI and/or VI. Despite the perception that older people do not use digital technology,[65,66] this review suggests that they *are* able to use it but are reluctant to change their established routines to do so.

Strengths and limitations

The review adopted standard scoping review methodology as well as independent duplicate assessment at every stage, thereby reducing the risk of bias. A broad range of databases was used to increase the likelihood of identifying relevant studies. The included studies were conducted in countries from the global north and south (demonstrating the universal challenge of medicine management by people with sensory impairment), thereby increasing the generalizability of the results. The quality of the included studies was highly variable.

The identification and inclusion of only one technology for people with HI is a limitation and is likely to reflect a paucity of empirical exploration in this population.

Conclusions

Despite a proliferation of medicine-related assistive technologies, there has been limited empirical evaluation of their effectiveness for supporting individuals with sensory impairment. Prototypes appear to be useful for people with visual or HI; however, more extensive 'real-life' testing is needed to confirm the benefits of these technologies.

To improve the utility and usability of assistive technologies for older people with sensory impairment, their involvement is needed using a co-design process, from conceptualization to evaluation.

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Conflicts of interest

There is no conflict of interest in this project.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dhjo.2023.101500.

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