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Abstract

Interventions for people with perceptual disorders after stroke: the PIONEER scoping review, Cochrane systematic review and priority setting project

Christine Hazelton,[1*] Alex Todhunter-Brown,[1] Pauline Campbell,[1] Katie Thomson,[1,2] Donald J Nicolson,[3,4] Kris McGill,[1] Charlie SY Chung,[5] Liam Dorris,[6] David C Gillespie,[7] Susan M Hunter,[8] Linda J Williams[9] and Marian C Brady[1]

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Background: Stroke often affects recognition and interpretation of information from our senses, resulting in perceptual disorders. Evidence to inform treatment is unclear.

Objective: To determine the breadth and effectiveness of interventions for stroke-related perceptual disorders and identify priority research questions.

Methods: We undertook a scoping review and then Cochrane systematic review. Definitions, outcome prioritisation, data interpretation and research prioritisation were coproduced with people who had perceptual disorders post stroke and healthcare professionals.

We systematically searched electronic databases (including MEDLINE, EMBASE, inception to August 2021) and grey literature. We included studies (any design) of interventions for people with hearing, smell, somatosensation, taste, touch or visual perception disorders following stroke. Abstracts and full texts were independently dual reviewed. Data were tabulated, synthesised narratively and mapped by availability, sense and interventions. Research quality was not evaluated.

Our Cochrane review synthesised the randomised controlled trial data, evaluated risk of bias (including randomisation, blinding, reporting) and meta-analysed intervention comparisons (vs. controls or no treatment) using RevMan 5.4. We judged certainty of evidence using grading of recommendations, assessment, development and evaluation. Activities of daily living after treatment was our primary outcome. Extended activities of daily living, quality of life, mental health and psychological well-being perceptual functional and adverse event data were also extracted.

Results:

Scoping review: We included 80 studies (*n* = 893): case studies (36/80) and randomised controlled trials (22/80). No stroke survivor or family stakeholder involvement was reported. Studies addressed visual (42.5%, 34/80), somatosensation (35%, 28/80), auditory (8.7%, 7/80) and tactile (7.5%, 6/80) perceptual disorders; some studies focused on 'mixed perceptual disorders' (6.2%, 5/80 such as taste–smell disorders).

We identified 93 pharmacological, non-invasive brain stimulation or rehabilitation (restitution, substitution, compensation or mixed) interventions. Details were limited. Studies commonly measured perceptual (75%, 60/80), motor-sensorimotor (40%, 32/80) activities of daily living (22.5%, 18/80) or sensory function (15%, 12/80) outcomes.

Cochrane systematic review: We included 18 randomised controlled trials (*n* = 541) addressing tactile (3 randomised controlled trials; *n* = 70), somatosensory (7 randomised controlled trials; *n* = 196), visual (7 randomised controlled trials; *n* = 225) and mixed tactile-somatosensory (1 randomised controlled trial; *n* = 50) disorders. None addressed hearing, taste or smell disorders. One non-invasive brain stimulation, one compensation, 25 restitution and 4 mixed interventions were described. Risk of bias was low for random sequence generation (13/18), attrition (14/18) and outcome reporting (16/18). Perception was the most commonly measured outcome (11 randomised controlled trials); only 7 randomised controlled trials measured activities of daily living. Limited data provided insufficient evidence to determine the effectiveness of any intervention. Confidence in the evidence was low–very low.

Our clinical (*n* = 4) and lived experience (*n* = 5) experts contributed throughout the project, coproducing a list of clinical implications and research priorities. Top research priorities included exploring the impact of, assessment of, and interventions for post-stroke perceptual disorders.

Limitations: Results are limited by the small number of studies identified and the small sample sizes, with a high proportion of single-participant studies. There was limited description of the perceptual disorders and intervention(s) evaluated. Few studies measured outcomes relating to functional impacts. There was limited investigation of hearing, smell, taste and touch perception disorders.

Conclusion: Evidence informing interventions for perceptual disorders after stroke is limited for all senses.

Future work: Further research, including high-quality randomised controlled trials, to inform clinical practice are required.

Study registration: This study is registered as PROSPERO CRD42019160270.

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Supplementary material can be found on the NIHR Journals Library report page (https://doi.org/10.3310/WGJT3471).

Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

Glossary

a priori Reported in advance.

Adverse event Any untoward and unintended response to an intervention.

Auditory (hearing) Processing and understanding auditory (hearing) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret auditory information.

Auditory processing disorder A hearing problem that affects how the brain interprets sound rather than how sound is carried through the ear to the brain.

Bias An error or deviation in results or inferences from the truth. In health care, the main types of bias arise from systematic differences in groups compared, the care provided, exposure to other factors, withdrawals/exclusions of participants or outcomes assessed. Reviews may show bias by reporting a subset of relevant data.

Brain stimulation Inhibiting or activating the brain through electricity.

Case-controlled study A retrospective study that looks at two groups (one with and one without an outcome) to assess if there is a difference between the groups.

Case report A study that describes and interprets an individual case, often written in the form of a detailed story.

Case series A descriptive study that follows a group of patients who are undergoing the same treatment over a certain period of time.

Charles Bonnet syndrome Hallucinations caused by loss of vision. The hallucinations may be simple patterns, or detailed images of events, people or places.

Cochrane Review A Cochrane Review is a systematic review of research in health care and health policy that is published in the Cochrane Database of Systematic Reviews.

Cognitive Skills such as reasoning, memory or attention.

Cohort study One where a group of participants are all given the same treatment, with measures before and after treatment to explore any changes that have occurred.

Comparison An intervention (i.e. active control) or placebo, used as a reference in a clinical trial.

Compensatory intervention Training the use of an undamaged function, using it to help compensate for the one that has been affected.

Confidence intervals The range of values the true value lies within.

Dichotomous variables One of two possible values.

Evidence map Results in a user-friendly (often visual) format (web).

Gustatory (taste) Processing and understanding gustatory (taste) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret gustatory information.

Haemorrhagic (stroke) Bleeding into or within the brain.

Heterogeneity Variability among studies.

Homogeneity Similarity between studies.

Intervention The treatment used.

Ischaemic (stroke) When the normal blood supply to part of your brain is cut off.

Meta-analysis Combining data from multiple independent studies. May be undertaken in evidence syntheses.

Modality (mode) How an intervention is provided.

N-of-1 (Also called a single-patient trial) is a study design which focuses on each individual participant, rather than grouping the results from all the participants together.

Nominal group technique A structured method that encourages contributions from all group members and facilitates agreement or decision-making.

Non-invasive brain stimulation Use of probes carefully placed on the skull to alter brain activity.

Olfactory (smell) The sense of smell. Processing and understanding olfactory (smell) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret olfactory information.

Outcome measure A component of a participant's functional status after an intervention has been applied, that is used to measure the effectiveness of an intervention.

Perception Perception is the ability of the brain to interpret and integrate information detected by the different sensory systems; *also* Specific mental functions of recognising and interpreting sensory stimuli; *also* Processing and understanding information from the senses.

Peto odds ratio A method for pooling odds ratios.

Pharmacological interventions Drug treatment.

Placebo An inactive intervention to compare its effects with those of an active intervention. Placebos are used in clinical trials to blind people to their treatment allocation. Placebos should be indistinguishable from the active intervention to ensure adequate blinding.

Proprioceptive deficits A problem with perception or awareness of the position and movement of the body.

Pusher syndrome Is characterised by leaning and active pushing towards the paralysed side, affecting their posture and possibly leading to instability and loss of balance.

Randomised controlled trial A study design that randomly assigns participants into an experimental group, which receives the treatment, or a control group, which does not. It is considered to provide the most reliable evidence on the effectiveness of interventions.

Restitution intervention Direct training of impaired function, to try and recover this.

Scoping review Exploratory projects that systematically map the literature available on a topic, identifying key concepts, theories, sources of evidence and gaps in the research.

Sensitivity analysis A repeat of the primary analysis or meta-analysis, substituting alternative decisions or ranges of values for decisions that were arbitrary or unclear.

Somatosensation Processing and understanding somatosensory information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret somatosensory information (includes proprioception).

Somatosensory deficit A difficulty with being able to process or understand mental functions of pressure, temperature or body position.

Substitution intervention Using external devices or adaptation of environment to help the person cope better.

Systematic review A review of a clearly formulated question that uses explicit methods to identify, select and critically appraise relevant research, and to collect and analyse data from the studies. Statistical methods (meta-analysis) may or may not be used to analyse and summarise the results of the included studies.

Tactile (touch) Tactile is described as understanding information from the skin. Processing and understanding tactile information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret tactile information.

Taxonomy System used to name and organise concepts.

Vision Processing and understanding visual (vision) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret visual information.

Visual agnosia A condition in which a person can see but cannot recognise or interpret visual information, for example an inability to name or describe the use of an object placed in front of you when just looking at it.

Visual hallucinations Hallucinations involving visual stimuli.

Visual perceptual deficits Having difficulties with the processing or understanding the mental functions of being able to distinguish, discriminate, recognise and interpret visual information.

Visual–spatial deficits Having difficulties with processing or understanding where items are in space.

List of abbreviations

ACTIVE framework	Authors and Consumers Together Impacting on eVidencE framework
ADLs	activities of daily living
EADLs	extended activities of daily living
ENT	ear, nose and throat
GRADE	grading quality of evidence and strength of recommendations
HCP	healthcare professional
ICF	International Classification of Functioning, Disability and Health
MD	mean difference
MVPT	Motor-Free Visual Perception Test
NFB	neurofeedback
NIBS	non-invasive brain stimulation
NIHR	National Institute for Health and Care Research
NMAHP	Nursing, Midwifery and Allied Health Professionals
OT	occupational therapist
PIONEER	perceptual disorders after stroke Intervention Evidence Review
PPI	patient and public involvement
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
QoL	quality of life
RCP	Royal College of Physicians
RCT	randomised controlled trial
rNSA	revised Nottingham Sensory Assessment
rTMS	repetitive transcranial magnetic stimulation
tDCS	transcranial direct current stimulation
TIDieR	Template for Intervention Description and Replication
WHO	World Health Organization
WVRT	WiiFit virtual reality training

Plain language summary

After a stroke, individuals may have difficulty understanding information gathered through their sense of sight, hearing, smell, taste, touch or somatosensation (body position, temperature, etc.), known as perceptual problems. We estimate perceptual problems affect around 240,000 stroke survivors in the UK, limiting their ability to understand the world around them, affecting everyday activities and reducing quality of life. Healthcare professionals may offer different treatments; medicine, brain stimulation, or rehabilitation activities including puzzles, strategies or physical therapy. We wanted to find the best treatments for stroke-related perceptual problems.

We searched for all research on sight, hearing, smell, taste, touch and somatosensation perceptual treatments to find out (1) how well they worked, (2) what the research means for stroke survivors and healthcare professionals and (3) what research is needed next. People with stroke-related perceptual problems and healthcare experts produced this research together.

We found 80 studies, involving 893 stroke survivors, describing 93 treatments. Eighteen of these studies used higher-quality randomised controlled trial designs; 535 stroke survivors took part, testing 32 treatments. Randomised controlled trials are important as one-half of those involved receive treatment and one-half do not; they provide the best evidence about whether a treatment works. Most treatments were for visual or somatosensation problems. Each study was small, provided few details about the participants or their treatment, and tested very different treatments. Few measured the effect of treatment on everyday life: only seven measured stroke survivors' ability to take part in everyday activities. No trial asked stroke survivors about their experiences with the treatments offered.

We do not have enough research to identify which treatments benefit the lives of people with stroke-related perceptual problems. We need more research into perceptual problems, especially the impact it has on stroke survivors' lives, as well as bigger studies into well-described treatments, that measure the impact of the treatment on people's lives.

Scientific summary

Background

Perception is the synthesis and interpretation of information gathered through the senses: hearing, taste, touch, smell, visual and information on temperature, pressure, vibration and body position, known as somatosensation. Up to a fifth of stroke survivors experience perceptual disorders after stroke, limiting their ability to perceive and process sensory information and reducing their ability to take part in daily activities. To date, the effectiveness of perceptual disorder interventions after stroke is unclear. Clinical guidelines offer limited recommendations. Stroke survivors, carers and healthcare professionals have stated that improving research into perception is important to them. Further, it is important to systematically identify evidence gaps and future research priorities.

Objectives

We aimed to:

- Identify all published and unpublished research evaluating interventions for perceptual disorders after stroke, providing a comprehensive report on the scope and nature of the evidence to date and highlighting the research gaps identified.
- Synthesise and appraise the quality of randomised controlled trial (RCT) evidence of the effectiveness of perceptual disorder interventions after stroke.
- Understand the implications of our findings for stroke survivors and HCPs working in this area and to determine future research priorities.

Methods

Our project included a scoping review, the revision and expansion of a Cochrane systematic review and we worked with a Lived Experience Group and a Clinical Expert Group to co-create research recommendations and identify research priorities.

Our scoping review of the literature was based on a systematic search of several electronic databases including MEDLINE, EMBASE and CINAHL (inception to August 2021), as well as searches of grey literature, contacting experts and forward citation tracking. We included studies of any design which explored interventions for stroke survivors with hearing, smell, somatosensation, taste, touch or visual perception disorders. Eligible abstracts and full texts were independently reviewed by two reviewers; data were extracted, tabulated and narratively synthesised. Data availability and outcome measures used were mapped. In keeping with scoping review methodology, we did not formally assess research quality.

We updated a Cochrane systematic review, including RCTs of adult stroke survivors with perceptual disorders. We assessed the risk of bias, conducted meta-analyses to explore effectiveness of interventions and judged our confidence in the findings using grading quality of evidence and strength of recommendations (GRADE). Outcomes were measured using activities of daily living (ADLs) with extended activities of daily living (EADLs), quality of life, mental health, perceptual function and adverse events data also collated.

Using structured involvement and priority setting approaches we worked in partnership with our Lived Experience and Clinical Expert Groups to agree clinical implications and to future research priorities.

Results

This project was coproduced with people with lived experience of stroke and perceptual disorders (*n* = 5) and relevant multidisciplinary clinical expertise (*n* = 4). Working in partnership with the core research team, these groups informed the project throughout, agreeing definitions of perception, relevant outcome measures, clinical implications and priorities for future research.

Scoping review

Of 91,869 records screened, we included 80 studies (including 36 case reports; 22 RCTs) in the scoping review, most (64%) of which were published in the previous decade. Participants (*n* = 893) were predominately adults and male; five children were included. Studies generally had small sample sizes, with RCTs accounting for most participants (70.5%; 630/893). The perceptual disorders represented included visual (43%), somatosensory (35%), auditory (9%), tactile (8%) or 'mixed' disorders (5%) which included one study on taste–smell disorders. We identified 93 interventions including rehabilitation (84%), pharmacological (6.5%) and non-invasive brain stimulation (NIBS) interventions (7.5%); no surgical or assessment-based interventions were identified. Intervention details were limited. Outcome measures commonly included perceptual function (75%), motor/sensorimotor (40%), ADLs (23%) or sensation (15%). No data on discharge destination, health economic, feasibility, educational (children), psychological well-being and mental health, quality of life, or activity and participation were reported. Time points were typically immediately after the intervention (39%) or within 3 months follow-up with just 15% of studies capturing outcomes beyond that time point.

Cochrane systematic review

Drawing on the scoping review results, the trials identified in a previous Cochrane Review and an updated search of bibliographic databases, 2575 records were identified. From these, 114 full texts were considered and 18 RCTs (*n* = 541) were included. All but six were stroke survivors, between 19 days and 4.3 years from onset.

The interventions included targeted visual (seven RCTs; *n* = 225), tactile (three RCTs; *n* = 70), somatosensory (seven RCTs; *n* = 196) and one mixed tactile-somatosensory disorders (one RCT; *n* = 50). No RCT evaluated interventions for stroke-related hearing, taste or smell disorders. Interventions included 1 NIBS, 1 compensatory, 25 restitution, 4 mixed and 1 unclear intervention approach. Seven included RCTs (39%) measured participants' ADLs though others captured perception (11 RCTs), adverse events (6 RCTs), mobility (4 RCTs) and EADLs (1 RCT). None measured activity and participation, quality of life or psychological well-being and mental health outcomes. We identified 11 ongoing RCTs.

The risk of bias of the included RCTs varied, with 72% describing adequate generate of the randomisation sequence and outcome assessor blinding, but concealment of allocation was considered adequate for only a third. Most trials adequately reported participant attrition (78%) and the outcome data gathered (89%). Other sources of bias were noted including an imbalance between the groups at baseline and altered eligibility criteria mid-RCT.

With limited data there was insufficient evidence to determine the effectiveness of any one intervention compared to no intervention or an alternative intervention. Based on the small number of RCTs, the small sample sizes and the limited comparisons available, our confidence in the evidence was, using GRADE, judged to be low–very low.

Strengths

Throughout this project, a Lived Experience and Clinical Expert Group were centrally involved in the development of definitions, categorisation, outcome measurement selection, interpretation of data and

research prioritisation, supporting clinical relevance and validity. The consensus working definitions and categorisations developed may support future research on this topic area. Our scoping and systematic reviews were conducted to the highest research conduct and reporting standards.

Limitations

Despite large numbers of people experiencing one or more perceptual disorder after stroke, there is a striking lack of relevant research to inform interventions. What little has been reported is often based on a single participant or small sample sizes. There is limited description of the perceptual disorder, the intervention(s) evaluated and a focus on perception outcomes rather than measures that reflect the functional impacts described by the Lived Experience Group, for example ADLs. We also found evidence of under-researched subpopulations including children and people with hearing, taste and smell perceptual disorders. The project team, Lived Experience and Clinical Expert Groups are UK-based, and it is unclear whether our priorities (outlined below) capture the wider international picture.

Priority setting

Our clinical expert (n = 4) and lived experience (n = 5) stakeholders' input was pivotal throughout the project. Together with the core research team, these groups agreed the clinical implications and research priorities emerging from the findings.

Implications for health care

Clinical recommendations include the facilitation of improved awareness of stroke-related perceptual disorders, assessment and information provision and holistic intervention approaches and support. While the research evidence was insufficient to support clinical decision-making relating to the choice of intervention approach, the scoping review provides an important information resource for clinicians developing best practice until sufficient evidence becomes available.

Recommendations for research

The evidence informing interventions for perceptual disorders after stroke is limited, and absent for smell, taste and tactile disorders. Future research should prioritise (1) exploration of the lived experience of people with stroke-related perceptual disorders, (2) improving assessments of stroke-related perceptual disorders, (3) exploring interventions in a way that reflects real-world needs, (4) exploring current clinical practices that address perceptual disorders following stroke and (5) establishing the prevalence of perceptual disorders after stroke.

Conclusions

Healthcare professionals lack high-quality evidence of effective interventions to inform their provision of advice, treatment and education of stroke survivors with perceptual disorders and their families. Evidence informing these research priority topic areas is urgently required.

Study registration

This study is registered as PROSPERO CRD42019160270.

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Chapter 1 Introduction

The Perceptual disorders after stroke Intervention Evidence Review (PIONEER) final report describes the project's three activities of scoping review, Cochrane systematic review and integration and priority setting with a stakeholder group. *Chapter 1* provides background information on perception and the project with *Chapter 2* giving an overview of the PIONEER project structure. *Chapters 3*, *4* and *6* outline the scoping, Cochrane Review and stakeholder engagement methodologies with *Chapters 5*, *7*, *8* and *9* reporting the results. The final chapters summarise our findings and how much confidence we have in those findings (see *Chapter 10*), comparing them to the existing literature, considering the project's strengths and limitations, and our recommendations for clinical practice and research (see *Chapter 11*). Sections of the report are reproduced from the PIONEER protocol[1] which is available to download from the National Institute for Health and Care Research (NIHR) journals library, with associated published versions of the work referenced throughout.

Perception

What is perception?

Perception is the brain's ability to integrate and interpret information detected by the different sensory systems including hearing (auditory), taste (gustatory), touch (tactile), smell (olfactory), somatosensory and visual systems. Somatosensation is a mixed sense, relating to temperature, pressure, vibration and body position (proprioception); some consider touch a component of this also. Perception involves multiple steps in processing sensory information: organising, assigning meaning and creating an understandable representation of the sensory landscape.[2] Perception is an umbrella term for various abilities, that are both successive and interactive.[3] In vision, for example, perceptual abilities range from perceiving simple physical characteristics in a scene, such as shape and colour, to 'higher' level skills including recognition and visuoconceptual processing.[4]

PIONEER definition of perception

Detailed, working definitions of perception are a challenge, with variations in the scope and components included: consensus remains elusive. The delineation between perception and sensation, attention and cognition is one aspect of this – sensation and perception can be conflated, but perception can also be considered one of several cognitive abilities.[2,5] Conceptual differences often vary by disciplinary background, theoretical approach, research methodology and geographic location, and these also vary with time. The lack of an agreed definition of perception has been a challenge encountered by previous reviews of interventions for perceptual disorders after stroke.[6]

Working with our Lived Experience and Clinical Expert stakeholder groups we explored the issue and developed a feasible, working definition for our project [see sections *Stakeholder activities (what happened)* and *Types of participants: defining perception*]. We used the World Health Organization's (WHO) International Classification of Functioning, Disability and Health (ICF) definition of perception – the 'specific mental functions of recognizing and interpreting sensory stimuli'[7,8] (ICF code b156). This definition (1) provides a very clear distinction between perception and other closely related functions of sensation and cognition; (2) is applicable to all senses and not just vision; and (3) is internationally accepted. We excluded sensory disorders (ICF code b2) and disorders of attention (ICF code b140, encompassing visual neglect), which have a separate evidence base.[9,10]

Using this definition meant automatic exclusion of a range of functions ('consciousness, orientation, attention, memory; language; seeing; hearing; and additional sensory functions').[7,8] We therefore excluded disorders relating to (1) sensation (ICF code b2; including visual field loss) and (2) attention (ICF code b140, encompassing visual neglect), which have been classified as 'perceptual' in prior research. While we recognise both are closely associated with perception, we considered each to be inherently

different from it: sensation arises 'earlier' in the process of acquiring and processing visual information and it relates to detecting the presence of sensory information while attention is the ability to attend to sensory information. In addition, sensory and attentional disorders will present and will often be assessed and treated differently from perceptual ones. Further, both sensory and attentional deficits have existing, separate evidence bases.[9,10] Thus, a review that focuses on perception as defined by WHO provides an evidence base that is unique, and maximally clinically relevant.

Perceptual disorder aetiology

Perceptual disorders can arise from a range of conditions. Neurological aetiologies are prevalent, with perceptual disorders associated with sudden onset conditions of stroke or head trauma, and also neurological disease, including meningitis, Parkinson's disease,[11] Alzheimer's and Lewy-body dementia.[12,13] In children, developmental disorders, including cerebral palsy,[14] can affect perception, while increasingly research suggests that processing of sensory information, especially relating to vision and touch[15] may be impacted among people with autism.[16] Psychiatric conditions[13] including schizophrenia and depression are associated with visual, taste and smell disorders.[11]

The PIONEER project focuses on perceptual disorders occurring because of stroke.

Perceptual impairment in stroke

Nature, incidence and prevalence

An estimated 100,000 people living in the UK have a stroke each year,[17,18] a number forecasted to rise by 59% over the next two decades.[19] Over 1.2 million UK adults live with the long term-consequences of their stroke.[20] The average age of an individual with stroke ranges from 71 to 78 years, but around one-quarter of strokes now occur in a person of working age.[17] Overall, the presentation of stroke-related perceptual disorders and natural recovery is poorly understood.[21] While significant improvement may occur the first 6 months after onset[22] longer-term prevalence data are highly variable. Available data suggest a wide range of prevalence figures, from 5% to 75% (see below). Using examples from somatosensation, we estimate that around one-fifth, or 240,000 stroke survivors in the UK may have a perceptual disorder.[23,24]

Information on the incidence, prevalence and natural history of perceptual disorders after stroke has been neglected in research. We are aware however that deficits can affect a broad range of perceptual skills relating to an isolated sense, or alongside disorders in other sensory modalities.

Visual perceptual disorders

Visual perceptual disorders have perhaps been studied in greatest depth. Prevalence rates show much variation: disorders are self-reported by 5.2% of stroke survivors at the acute stage.[25] However, objective assessment suggests that visual perceptual disorders have a prevalence of 69% 1 month after stroke and in 74% at 2 years post stroke.[26] Deficits in recognition (agnosia) include visual objects, body parts, faces and non-verbal expressions. Spatial perceptual difficulties affect depth perception, location judgement and impair perception of motion. Stroke survivors may experience difficulties organising or integrating visual information, with a complex scene presenting difficulties for the stroke survivor's identification of specific components, differentiation of foreground from background and deciding which parts belong together.[2,4,5]

Hearing perception disorders

Hearing perception deficits may include difficulty with locating sounds, recognising auditory patterns, discriminating of speech from non-speech sounds, temporal aspects of auditory information (integration, resolution, ordering) and difficulty processing competing acoustic signals.[27] There are limited data on the prevalence of auditory perceptual deficits after stroke, as hearing is not routinely assessed; one case-controlled study of peripheral and central hearing loss reported a prevalence of 40% among younger (18- to 60-year-old) stroke survivors.[28]

Smell and taste disorders

Stroke is also associated with perceptual disorders that present as smell dysfunction[29,30] or taste impairment.[31] Almost one-third of stroke survivors may have some loss of taste, with 6% experiencing lateralised impairment of taste 1 week after stroke.[32] Smell dysfunction has been noted in 43% of stroke survivors a year after stroke, with odour perception reduced (29.7%) or absent (10.8%).[33]

Somatosensation disorders

Somatosensation refers to sensation arising from the skin, muscles or joints,[34] and includes perception of pressure, vibration, temperature and proprioception (kinaesthesia, joint position, movement, action and location). Stroke can cause deficits in one or a combination of these perceptual areas. Somatosensory impairment occurs in 34–63% of stroke survivors in the early phase (average 15 days post stroke), varying with the area of the body tested.[22]

Touch disorders

Perception of touch is frequently impaired after stroke, reduced by up to 85% on the contralesional side in the acute and subacute phases;[22,35,36] in the first 3 weeks up to 89% of stroke survivors can be affected,[22] estimated to fall to 33% in the longer term.[35] Deficits can impair stroke survivors' tactile recognition, including discrimination of texture, shape and length, and object recognition.[22,36]

Impact of perceptual disorders after stroke

Perceptual disorders will reduce an individual's ability to understand their environment and respond appropriately to it; for example, stroke survivors with visual perceptual disorders may not recognise family members, while spatial difficulties may cause disorientation and anxiety in busy environments, leading to reluctance to leave the home.[37] Visual perceptual dysfunction is associated with reduced abilities in activities of daily living (ADLs),[38] greater disability, poorer quality of life (QoL)[39] and can predict self-care difficulties.[40]

Auditory perceptual disorders impact on listening skills and are likely to contribute to poorer auditory comprehension and communication abilities. Stroke assessments and interventions are typically based on healthcare professionals' spoken instruction. Stroke survivors that have trouble communicating will also experience difficulties in diagnosis, and rehabilitation participation.[28,41,42]

Taste dysfunction can lead to subjective unpleasantness when eating, impaired appetite, dietary changes, malnutrition and weight loss. Stroke survivors who are malnourished have poorer outcomes and require longer hospital admissions.[43,44] The inability to smell negatively impacts on eating, social communication and safety (e.g. detecting a gas leak).[45]

Altered perception of the various components of somatosensation can lead to poorer performance of motor tasks, particularly control of fine motor skills in the hand (such as grip control, touch, pressure, proprioception),[46] greater risk of accidents and injuries such as scalds and burns (temperature), increased incidence of falls[28] (proprioception, learned non-use of limbs)[47] and is linked with poor recovery of motor function and reduced independence in ADLs.[48] Those affected by altered somatosensory perception have greater activity limitations and longer hospital stays.[49]

While there is evidence of the effect of perceptual impairments on stroke survivors' rehabilitation outcomes and ability in everyday tasks, there is very limited exploration of the lived experience of such disorders, across the different senses. Stroke survivors and carers may well not recognise or understand that a problem they experience is due to impaired perception, and such find it a 'puzzling and disabling.'[50] Where perceptual disorders are not assessed and/or identified (see *Poor documentation and variability*) the nature of the issue can be mistakenly attributed to disorders of communication, memory, balance or motor skills. Where stroke survivors are aware of their perceptual impairment(s), they can have difficulty articulating their experiences of this[51] but can detail the extra time and effort needed to accomplish tasks 'You just have to be so methodical, so slow and it takes me forever to do stuff'[52] and associated

frustration. In addition, there are a range of emotional consequences: despair, anger, changes in self-confidence, feelings of worthlessness, vulnerability and changes in personal identity.[52] A number of online resources exist to inform and support carers and stroke survivors affected.[53,54]

Interventions for perceptual disorders after stroke

The current literature offers some proposed interventions for the management of perceptual disorders after stroke: common to all six sensory areas are screening and assessment interventions to enable timely and accurate diagnosis.[28,33,55–57] Treatment approaches are primarily rehabilitative, aiming to compensate for the loss of function, but these vary depending on the sense affected and the nature of the dysfunction.

Therapeutic approaches to visual disorders may include sensory stimulation (visuo-perceptual tasks),[58,59] functional training (everyday tasks)[60] and strategy training (alternate strategies to achieve goals) including the use of other senses to do so.[61–63] More recent interventions have used computer-based virtual reality training,[64,65] incorporated visual and auditory feedback,[66] or used transcranial direct current stimulation (tDCS) to stimulate the brain.[67] For auditory perception disorders, approaches may include environmental modifications, assistive listening devices,[68] development of compensatory strategies or auditory training, which aims to improve the affected auditory process(es) through challenging listening tasks.[69]

Few stroke-related olfactory and gustatory dysfunction treatments are reported:[70] Pharmacological approaches have been considered,[71] as well as referral to a dietitian for advice.[72] For impaired touch perception, interventions have focused on the upper limb, and include retaining sensory recognition and discrimination using specialist equipment.[73] Interventions for somatosensory perceptual deficit vary dependent on the specific function targeted but may include courses of sensory retraining using a range of stimuli,[74] or targeted physiotherapy, which may incorporate robotic or highly specialised equipment.[75]

Current services for perceptual impairment after stroke

Poor documentation and variability

Descriptions of current screening, assessment, treatment and referral pathways for stroke survivors with perceptual disorders are limited and variable. As perceptual impairments can affect all six senses, where services exist, they may be delivered by one of several healthcare professions (HCPs), including occupational therapists (OTs), physiotherapists, doctors, psychologists, orthoptists, audiologists and ear, nose and throat (ENT) services. HCPs and members of the public may be unaware of the range of perceptual impairments across hearing, smell, somatosensation, taste, touch and vision that may present after stroke and disorders may go unreported, under diagnosed or untreated.[43,76–78] Where UK service data are available, provision for visual disorders varies greatly[76,79,80] with lack of standardised tests and procedures.[81] There are several barriers to effective service delivery, one of which is an evidence base on which to base treatment decisions.[79,80,82,83]

Limited research informing clinical guidelines

Guidelines highlight the paucity of perceptual disorder intervention research on which to base clinical recommendations.[3,84,85] UK stroke clinical guidelines for adults (which are in update) refer to perceptual disorders, but not all sensory modalities are mentioned: three consider vision, one considers sensation (appearing to include tactile perception), and none make recommendations on hearing, taste or smell dysfunction.[3,84,85] The Royal College of Physicians (RCP) clinical guideline for stroke is the most comprehensive but focuses solely on visual perception, and agnosia (impaired object recognition), a specific visual disorder. The existing guidelines based their recommendations on a historic Cochrane Review[6] which found no evidence of benefits for perceptual disorders after stroke.

Orthoptists' clinical guidelines refer only to visual agnosia and hallucinations (recommending the provision of information) and the evidence underpinning these recommendations is unclear.[86] Paediatric

stroke guidelines noted the absence of relevant research evidence and recommend the assessment of vision and hearing. Specialist support services and functional impacts, and tactile stimulation was also suggested for children with altered upper limb sensation.[87] These best practice recommendations were based on the opinion of the guideline development group.

Existing reviews of interventions for perceptual impairments in stroke

A comprehensive review of the evidence relating to all perceptual disorders after stroke has not been conducted to date. The reviews relevant to this topic have limitations as they may:

1. Include interventions for non-perceptual deficits, such as visual perceptual disorder reviews which include attentional deficits[88] and those of touch and somatosensation which include sensory impairments.[89]
2. Relate to a small subset of perceptual impairments within one sense, rather than considering all perceptual disorders relating to the sense as a whole.[90]
3. Have a clear focus on exploring interventions for visual disorders, to exclusion of other senses.
4. Include non-stroke populations, making clinical interpretation challenging.[6]

The need for this project

Across the six senses there are many interventions targeting perceptual disorders after stroke. Reviews of the evidence to date are limited. A lack of evidence and the resulting evidence uncertainties mean that stroke and rehabilitation clinical guidelines are unable to provide clinicians with evidence-based recommendations. Clinicians, aware of the limitations imposed on clinical practice by a lack of intervention research,[62] have called for research to support both assessment methods and treatment approaches.[63] Perceptual disorders are likely to have an important impact on stroke survivors: identifying effective interventions for such impairments is a research priority in stroke rehabilitation and long-term care for stroke survivors, carers and clinicians.[91–93]

The PIONEER study aimed to review the evidence of interventions for perceptual disorders following stroke, to highlight evidence of benefits, research gaps and future research priorities.

Aims and objectives

We aimed to identify, review and synthesise the evidence relating to interventions for the management of perceptual disorders following stroke. The three objectives were:

1. to identify all research (published and unpublished) relating to interventions for perceptual disorders after stroke, giving a comprehensive overview of the scope and nature of that evidence, and using this to highlight evidence gaps
2. to synthesise high-quality randomised controlled trial (RCT) evidence of the clinical and cost-effectiveness of interventions for perceptual disorders and appraise the quality of that evidence
3. to understand the implications of our findings for stroke survivors and HCPs working in this area and to determine future research priorities.

Chapter 2 Introduction

This chapter provides an overview of the PIONEER project, consisting of a scoping review, revision and expansion of a Cochrane Review and an integration and priority setting process (*Figure 1*). Active stakeholder involvement was integral to the project.

Stakeholder involvement approach

To support involvement and coproduction of the PIONEER project we used a multifaceted approach, to maximise the quality, relevance and accessibility. The methods are detailed in *Chapter 3*, and involved:

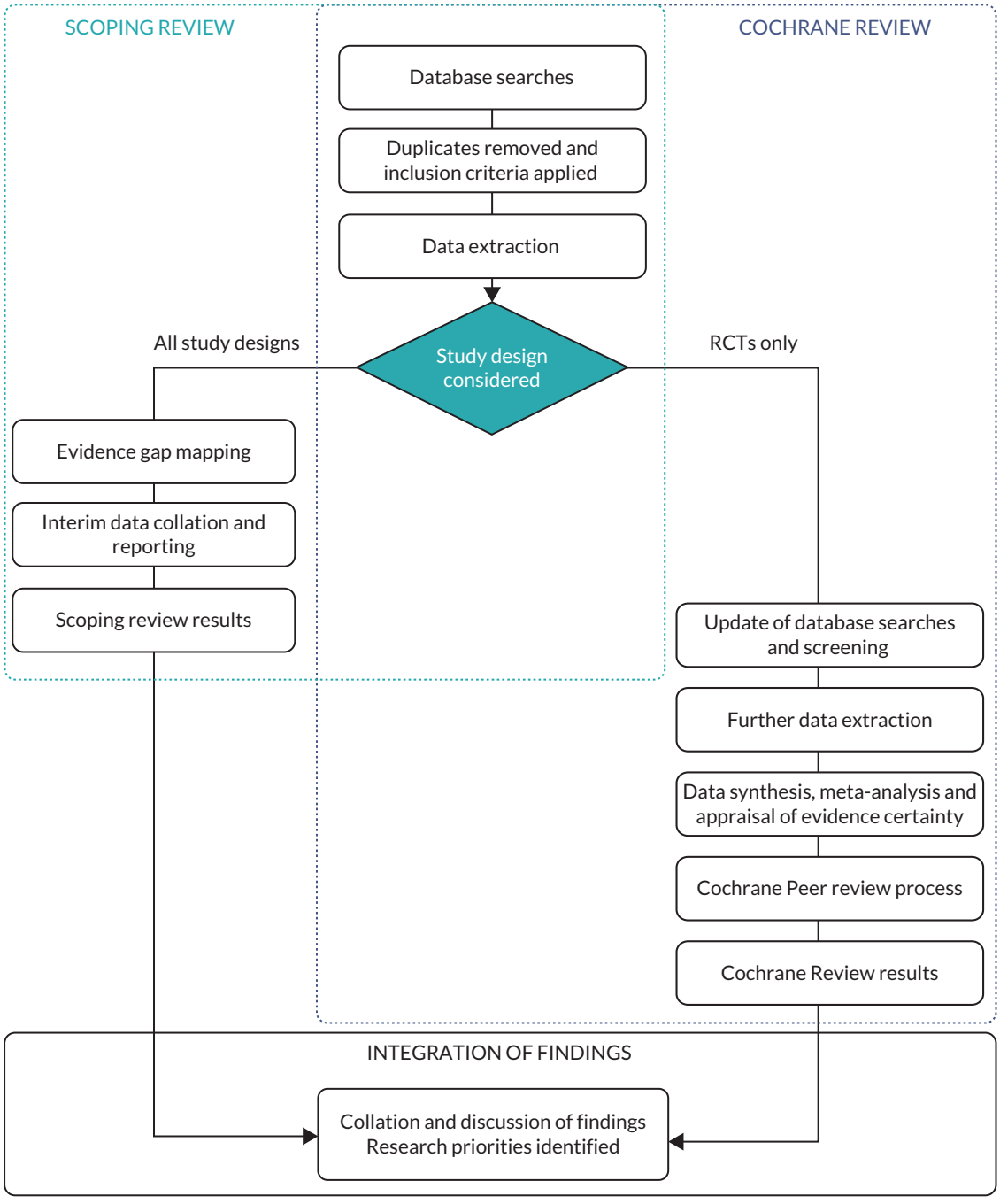

FIGURE 1 Flow chart of the three project components.

1. coproduction with co-applicant (DJN) who has lived experience of perceptual problems after stroke;
2. Lived Experience Group: five volunteers with personal experience of stroke and associated perceptual problems or were a parent or carer of someone affected;
3. Clinical Expert Group: four clinicians with a range of expertise in relevant specialities that complimented the clinical expertise of the research team.

The project structure/overview

Systematic scoping review with evidence gap mapping

We undertook a scoping review of the literature to identify all evidence relating to interventions for perceptual disorders after stroke (see *Aims and objectives*). Scoping reviews map a broad field of literature, an approach ideally suited to this objective, given the variety of perceptual problems occurring post stroke, and the wide range of potential interventions.

Adhering to published guidance we followed a six-stage scoping review framework, including thorough searching and broad study design inclusion criteria.[94] We searched the relevant research comprehensively, working alongside our stakeholder groups and information specialist (JC) to develop a rigorous exploration of the existing literature.[95] We included **all interventions, all participant age groups, settings, study designs** (including quantitative and qualitative methods) and **outcomes** relating to interventions for perceptual disorders. Results were tabulated and summarised narratively. Details of the systematic scoping review methods (see *Chapter 4*) and results (see *Chapter 5*) are provided later.

Cochrane systematic review

We undertook a Cochrane systematic review and meta-analysis, exploring RCT evidence of the effectiveness of interventions for perceptual disorders after stroke (Objective 2). Cochrane Review methodologies provide the highest quality approach for synthesis of evidence intervention effectiveness.[96] We revised, expanded and updated an existing Cochrane Review[6] published in 2011. We narrowed the review's participant eligibility criteria to focus on stroke participant populations while expanded the intervention eligibility criteria to include all treatment approaches.

We identified, appraised and synthesised the relevant evidence from RCTs to determine where sufficient evidence exists of the benefits of a specific intervention for a perceptual disorder. We used the Template for Intervention Description and Replication (TIDieR) guidelines to maximise the clarity of our intervention data extraction and reporting[97] and the grading quality of evidence and strength of recommendations (GRADE) approach to appraise evidence certainty.[98] Details of the Cochrane systematic review methods and results are provided in *Chapters 6* and *7*.

Integration and priority setting

We explored the implications of our scoping and Cochrane systematic review findings relating to interventions for people with perceptual disorders after stroke and the HCPs working with them (Objective 3). We aimed to maximise the relevance and applicability of the synthesised evidence to clinical practice and future research, and to identify any barriers to the uptake of that evidence.[99]

Working with our Clinical Expert and Lived Experience Groups we interpreted our findings in the context of current clinical practice and stroke survivor experiences.[100] Using structured methods of involvement[101] and priority setting,[102] we agreed on the implications for clinical care in relation to: (1) stroke survivors and their carers; (2) HCPs providing care; and (3) policy-makers. We also prioritised the research gaps identified and developed recommendations for future research. Details of the methods and results are provided in *Chapters 3* and *8*.

Chapter 3 Introduction

Chapter 3 details the stakeholder involvement throughout the PIONEER project; our approach, recruitment strategy, tasks undertaken, the level of stroke survivor, carer and HCP involvement and an evaluation of the stakeholder involvement impact. The chapter is structured based on the Authors and Consumers Together Impacting on eVidence (ACTIVE) framework[103,104] and five stakeholder involvement in systematic reviews constructs: (1) who was involved, (2) how they were recruited, (3) when they were involved, (4) their level of involvement and (5) what happened. The methods involved in each stakeholder activity are also given, with contributions arising from our stakeholder involvement reported in relevant sections of *Chapters 4*, *5*, *7* and *8*; the impact of their contributions is described in *Chapter 9*.

Stakeholder involvement approach

To facilitate the contribution of a range of perspectives, experiences and knowledge, we used multifaceted stakeholder involvement including (1) a stroke survivor co-applicant, (2) a Lived Experience Group and (3) a Clinical Expert Group.

A co-applicant with lived experience of a stroke-related perceptual disorder (DJN) supported coproduction from project initiation: he was involved in the planning and conduct of all stages. His experience of systematic reviews relating to perceptual problems[6] made an important contribution to the coproduction of the PIONEER scoping and Cochrane systematic reviews. People with experience of perceptual problems after stroke participated in a Lived Experience Group, and HCPs participated in a Clinical Expert Group. Both groups used a structured involvement approach based on (1) the ACTIVE framework,[103,104] (2) the Involving People resources[105] and (3) stakeholder involvement approaches used in previous systematic reviews.[101]

Ethical approval and consent

United Kingdom guidance indicates that ethical approval is not required for stakeholder involvement activities[106]; however, as we planned to digitally record, store and report contributions made, we considered that seeking ethical approval was good practice. Glasgow Caledonian University's School of Health and Life Sciences Nursing Department Research Ethics Committee granted approval (HLS/NCH/19/021). Written consent for the recording and reporting of anonymised data was obtained from stakeholders prior to the first meeting. Verbal consent for the digital recordings was given at the start of meetings. Data were anonymised and written-up, with electronic data stored securely.

Stakeholder training

We provided essential training, including an introduction to evidence-based practice and systematic reviews, to all those involved. We also signposted members to relevant online training on specific topics, for example Cochrane Review training, as the need arose. Individualised training sessions, coaching and mentoring were also available but not requested.

Stakeholder payment

The Lived Experience Group members were offered payment for their time to attend meetings and review of documents at NIHR-INVOLVE recommended rates. Payment for eligible expenses, such as travel, was also met.

PIONEER stakeholder involvement methods

Who was involved?

The Lived Experience Group were individuals aged 18 years or over, with personal experience of stroke-related perceptual problems, or as the parent or carer of a stroke survivor with perceptual problems.

The Clinical Expert Group were HCPs with expert knowledge of at least one sense addressed in this project. Clinical expertise was sought to complement that of the clinical research team, ensuring input relating to all senses, ages and healthcare settings, as well as a range of geographic locations.

How were people recruited?

Lived Experience Group

The opportunity to participate was advertised via our established stroke research stakeholder group (NMAHP Research Unit Stroke Research Advisory Group), and NIHR INVOLVE website [www.PeopleInResearch.org (accessed September 2022)]. Recruitment was based on an opt-in strategy, and replies were considered as consent to contact. Telephone conversations between the lead researcher (CH) and those who replied explored the individual's experience of stroke and perceptual problems and the project's terms of involvement. Volunteers who met the predetermined group profile and were interested in participating joined the group, until five members were identified.

Clinical Expert Group

We sought four HCPs through existing networks and recent publications, with expertise in visual perception, hearing perception, taste and smell and paediatric specialisms. We invited them to participate by e-mail.

When were they involved?

Stakeholder involvement can occur at any stage of a systematic review.[107] We used two involvement approaches: stakeholders participated in planned meetings at set time points, and informal communication occurring as needed throughout the review.

Planned meetings: these were held in person or online to inform decision-making for: planning methods, search development, selecting studies, analysing data, interpreting findings and writing the review (*Figure 2*). Stakeholders met virtually or in person at least every 3 months.

Informal communication: we provided regular updates to, and gained input from, the stakeholder groups throughout the project via e-mail or online updates. Individual stakeholders were available for consultation throughout and were contacted as required; for example, specific clinical experts were consulted regarding a study's eligibility criteria during the study selection stage. Group members were invited to comment on draft abstracts, lay summaries and evidence gap maps via e-mail.

Level of involvement

We sought different levels of stakeholder involvement across the project:

- **Controlling** aspects of the review process – we pre-planned that several decisions would be made by the stakeholder group working in partnership with the research team. For example, the stakeholders controlled decisions about the outcomes of interest.
- **Influencing** the review activities and outputs – the stakeholders had a role in the review process and an opportunity to directly influence the review but stopping short of final decision-making control. For example, the stakeholders *influenced* the wording of statements relating to clinical implications.

Framework constructs	Categories		Icon
Who was involved?	**Patients, carers and/or their families**		
	Patients, carers and/or their families + other stakeholders		
	Other stakeholders only		
How were people recruited?	Open = Lived Experience Group	Fixed = same members	Fixed
		Flexible	
	Closed = Clinical Expert Group	Invitation	Invite
		Existing group	
		Purposive sampling	
	Other/unclear		
What happened? *Approach?*	**One-time**		
	Continuous		
	Combined (i.e. both one-time and continuous)		
What happened? *Methods?*	Direct interaction = meetings		
	No direct interaction		

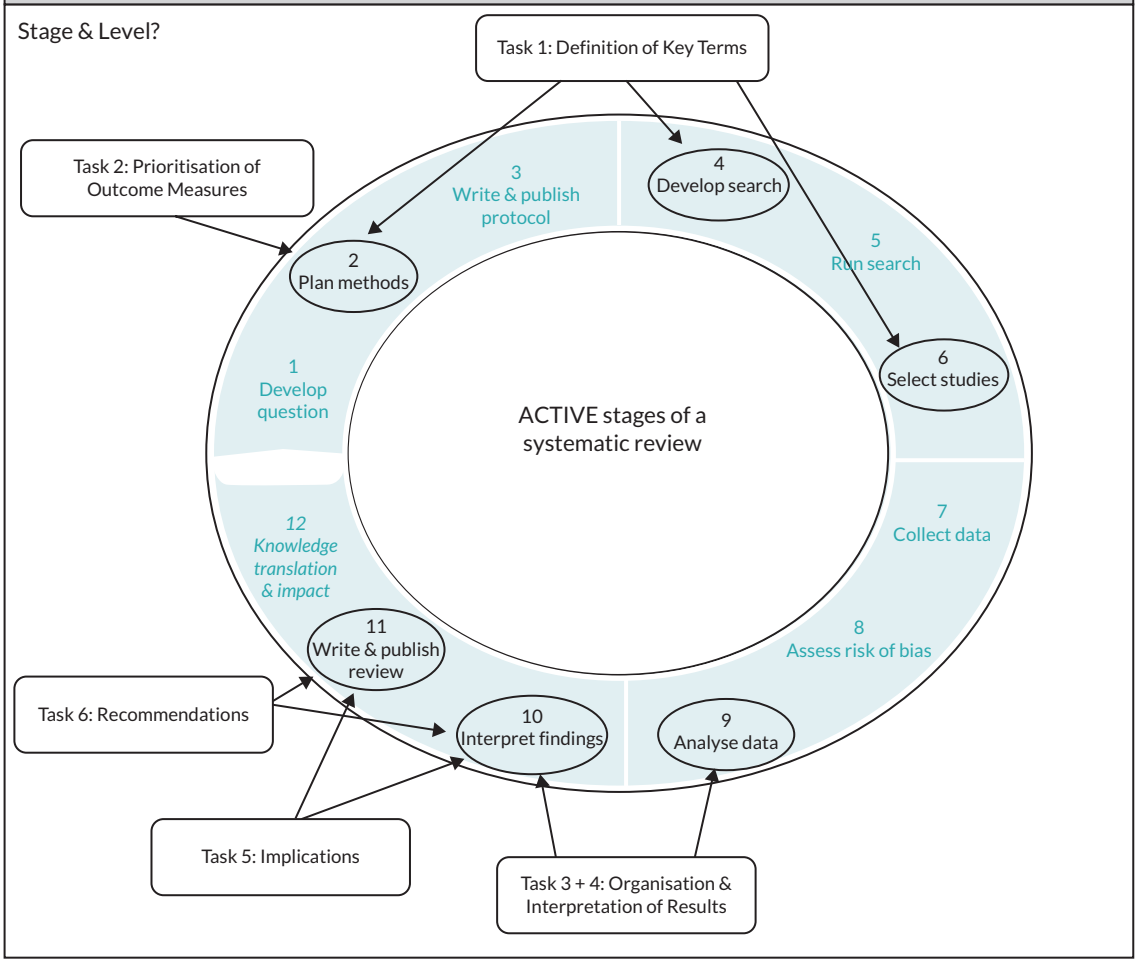

FIGURE 2 The involvement of stakeholders in this project.[2]

- **Contributing** throughout the review – stakeholders had the opportunity to take part in meetings, respond to e-mails and provide input which could indirectly impact on decisions made within the review.

We recorded group members' involvement and impact at each review stage. We also asked stakeholders to describe their perception of involvement for each of their activities. We have reported involvement using the GRIPP2 tool.[108]

Stakeholder activities (what happened)

Meetings adhered to the key principles of research coproduction, creating an environment that recognised everyone's contributions and in which people worked together to achieve a shared understanding.[109] Ground rules were agreed at the start of meetings which highlighted respect, inclusivity and joint ownership of decisions. We used practical techniques that facilitated participants' input (experienced facilitators, a timekeeper) and 'devolved' some decisions to the participants, ensuring that they had control over decision-making.[101]

We sought stakeholders' input on six planned review-related activities (see *Figure 2*):

1. definition of key terms
2. outcome measurement identification and prioritisation
3. interpretation of the scoping review results
4. interpretation of the Cochrane systematic review results
5. identifying clinical implications of the review findings
6. determining research gaps and priorities (see *Report Supplementary Materials 1–8*).

Activity 1: definition of key terms

We anticipated that operationalising the term 'perception' would be a challenge (see section *Perception*). The Lived Experience, Clinical Expert Groups and the research team sought a consensus agreement on a definition of perception and associated terminology and how these could be applied within the review process.

A full-day, face-to-face decision-making meeting was held at the project start (see *Report Supplementary Material 1*). Meeting participants were sent the WHO ICF perception definition (see *PIONEER definition of perception*) and draft definitions of key terms (such as visual, auditory, tactile, olfactory). Using a structured, facilitated discussion,[110] participants considered each proposed definition before reaching a consensus definition using voting.[101] Discussions relating to disorders that were complex in nature, or their categorisation as a perceptual disorder was unclear, led to a range of a priori inclusion or exclusion decisions being developed. For each included sense, members recorded on flip charts all perceptual disorders that they were aware of, using clinical or lay terminology. Moving cards containing key terms created a potential taxonomy, which was captured by photographs. Definitions determined the project scope and the inclusion and exclusion criteria while the list of perceptual disorders informed our literature search strategy.

Activity 2: outcome measure identification and prioritisation

A prioritised list of outcome measurements for inclusion in the Cochrane systematic review was coproduced with the stakeholder groups. The impact of perceptual problems on life after stroke was explored by the Lived Experience Group during a videoconference, and impacts were listed (see *Report Supplementary Material 2*). E-mail correspondence finalised the generated list, with similar impacts grouped into 'outcome measurement categories' in collaboration with the research team and with reference to existing reviews.[6,9,111] The stakeholder groups and research team ranked the outcome measurement categories from most to least important. Rankings were pooled to form a shared list (see *Report Supplementary Material 3*), and the results informed the selection of outcome measurements included in the scoping and Cochrane systematic reviews.

Activity 3: organisation and interpretation of scoping review results

The stakeholders and the research team attended two videoconferences to discuss interpretation of the scoping review findings. Written review finding summaries were circulated by e-mail prior to meetings, which included presentations by researchers. Facilitated discussions were digitally recorded (see *Report Supplementary Material 4*).

Activity 4: organisation and interpretation of Cochrane Review results

The stakeholders and the research team attended a 2-hour videoconference to discuss interpretation of the Cochrane systematic review findings. The meeting included an introductory 'What is a Cochrane Review?' presentation, an evidence overview of the Cochrane Review data, followed by the systematic review results relating to hearing, taste, smell, touch, somatosensation and vision. Stakeholders shared their thoughts on the results for each sense during a facilitated discussion. The meeting concluded with a results overview and the stakeholders suggested what they considered was the overall result and implications. Meeting notes were supplemented with discussion, and captured using digital audio-recording (see *Report Supplementary Material 5*).

Activity 5: clinical implications

The stakeholders contributed to the project's clinical implications based on the scoping review and Cochrane systematic review findings. They considered the findings from the perspectives of (1) stroke survivors and carers, (2) HCPs and (3) policy-makers. The stakeholders and the research team attended a 2-hour videoconference. Stakeholders received a written summary of the scoping and Cochrane systematic review results prior to the meeting, with review findings presented at the meeting. The Lived Experience Group discussed the results and the implications for stroke survivors and carers. The Clinical Expert Group and researchers considered the implications for HCPs. After regrouping, the meeting participants shared the key implications identified and agreed a list of implications for policy-makers. Notes taken during the meeting were supplemented with key discussion points captured in the digital audio-recording (see *Report Supplementary Material 6*).

Activity 6: research recommendations

Stakeholders sought consensus on the top research priorities for perceptual problems after stroke. During a 2-hour videoconference meeting, they generated a list of research gaps and questions relating to perceptual problems after stroke (see *Report Supplementary Material 7*). The research gaps were circulated by e-mail, providing an opportunity to contribute further. Questions relating to the broad topic of perceptual problems after stroke were then ranked by stakeholders from most to least important (see *Report Supplementary Material 8*).

Evaluation of impact of stakeholder involvement

After each meeting we asked stakeholders to provide their views about (1) what they felt they had contributed to and (2) how it impacted on the review. Throughout the project, we also documented any input from group members relating to project changes in response to their involvement.

A final meeting with the Lived Experience Group explored their views on involvement. They were provided with feedback from the research team on the impact of their involvement on the project and were asked to reflect on this and to discuss the impact that they considered they had made at different stages of the review process. They were asked what aspects of their involvement they felt had gone well, and what aspects they would change.

Summary

Our stakeholder involvement approach supported coproduction of six key tasks: defining key terms, prioritising outcome measures, interpreting the scoping and Cochrane Review results, agreeing clinical implications and identifying and prioritising research recommendations. This was supplemented by the less formal process of e-mail communication and input as needed. The results and outcomes of specific tasks are detailed in the relevant chapters; our evaluation of the impact of stakeholder involvement is presented in *Chapter 9*.

Chapter 4 Scoping review methods

Overview

This chapter details the rigorous methods used to scope and identify all research evidence (published and unpublished) relating to interventions for perceptual disorders after stroke, giving a comprehensive overview of the breadth and nature of that evidence, and using this to highlight evidence gaps. We present the scoping review framework used, the study inclusion criteria, the search and data organisation methods used. The data synthesis approach, interpretation of the findings and evidence gap mapping methods are also detailed below. This review has been published in the journal *Stroke*.[112]

Introduction

Scoping reviews scope and systematically map the literature in an area that may not have previously been reviewed[113] such as stroke-related perceptual disorders. This scoping review aimed to identify all available evidence relating to interventions for the management of perceptual disorders following stroke, providing an overview of the range, number and type of interventions, supporting the development of evidence gaps.

We employed Arksey and O'Malley's six-stage scoping review framework[94,114,115] to ensure rigour and transparency:

1. identifying the research question
2. identifying the relevant studies
3. study selection
4. charting the data (data extraction)
5. collating, summarising and reporting
6. consultation.

Two framework stages were augmented to maximise the relevance and accessibility of our results. Evidence gap mapping was added to stage 5 to enable visualisation of the evidence summaries and gaps identified[116] and the 'consultation' process involving stroke survivors, carers and clinical experts occurred throughout the review, rather than only at the end. The scoping (and systematic review) protocol was registered with the PROSPERO database CRD42019160270, as well as published online[1] and our reporting was supported by the relevant reporting guidelines.[117]

Criteria for considering studies for this review

The study inclusion and exclusion criteria are given in *Table 1* with definitions provided in *Box 1*.

TABLE 1 Study eligibility criteria

Study	Inclusion	Exclusion
Design	• Primary research studies including quantitative, qualitative or mixed methods • Published and unpublished studies • Any setting, geographical location, publication date or language	• Reviews, systematic reviews, commentaries
Participants	• Stroke survivors with perceptual disorders in any of the six sensory domains (see *Box 1*) • Perceptual disorders included (1) Pusher syndrome and (2) hallucinations, when related to the senses, and not arising from a psychiatric/psychological cause • All ages • Any time point post stroke	• Inattention/neglect, pain or vestibular disorder • Balance disorders (a function which utilises perceptual information rather than being central to perceptual processing)
Intervention	• Any intervention or treatment aimed at improving a perceptual disorder	• Studies that did not involve an intervention • Studies where the intervention was not specific to addressing the perceptual disorder (e.g. general stroke interventions, driving interventions, interventions for attention)
Comparator	• All comparators	• None excluded
Outcomes	• All quantitative or qualitative data Prioritised outcomes of interest: 1. ADLs 2. EADLs 3. Social activities and participation 4. Psychological well-being and mental health 5. QoL 6. Mobility, navigation and safety 7. Sensation, cognition, motor or sensorimotor ability or attention 8. Perceptual function 9. Impact on family, friends and carers 10. Paediatric-specific outcomes, for example development or educational attainment measures 11. Discharge destination 12. Feasibility and acceptability of interventions 13. Adverse events 14. Ability to compensate for perceptual impairment (using other skills) 15. Neurological function 16. Economic outcomes	• None excluded

BOX 1 Senses included in the scoping review with agreed definitions

- **Hearing** (auditory) – processing and understanding auditory (hearing) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret auditory information.
- **Smell** (olfactory) – processing and understanding smell (olfactory) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret olfactory information.
- **Touch** (tactile) – processing and understanding touch (tactile) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret tactile information.
- **Somatosensation** [temperature, pressure and body position (proprioception/kinaesthesia)] – processing and understanding somatosensory information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret somatosensory information.
- **Taste** (gustatory) – processing and understanding taste (gustatory) information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret gustatory information.
- **Vision** – processing and understanding visual information. This may include the mental functions of being able to distinguish, discriminate, recognise and interpret visual information.

Types of participants: defining perception

The definition of perception was determined via discussion and voting with our stakeholder groups [see *Stakeholder activities (what happened)*, Activity 1 and *Report Supplementary Material 1*]. Members agreed to use the WHO ICF definition of perception 'specific mental functions of recognizing and interpreting sensory without amendment or addition stimuli', with the creation of a lay definition of 'processing and understanding information from the senses' to assist with clearly communicating findings. Members discussed, created and voted to accept definitions of the individual senses included (see *Box 1*). It was decided that although touch could be considered a component of somatosensation this would be treated as distinct, to support the accessibility of the findings since touch is one of the 'traditional' five senses.

Discussion between the research team and stakeholders led to a priori decisions relating to the inclusion of specific disorders that were either complex in nature or their categorisation as a perceptual disorder was unclear. These covered Pusher syndrome (a disorder of perception of body position)[118] (included), hallucinations (included); balance, vestibular disorders and neglect (excluded). Studies that combined stroke and non-stroke populations were included and coded to indicate they were a mixed population (see *Participants included*). Studies that combined perceptual impairments with other disorders such as sensory or cognitive impairments were included and coded to indicate this (as perceptual, perceptual-sensory, perceptual-cognitive, mixed or unclear if the exact perceptual impairment could not be identified).

Types of interventions

Where interventions addressed perceptual disorders across more than one sense (e.g. smell and taste), these were included and coded to indicate the mixed grouping.

Types of outcome measures

Seventeen outcomes of interest were identified in collaboration with our stakeholder groups [see *Stakeholder activities (what happened)*, Activity 2 and *Report Supplementary Material 2*]. These were prioritised by stakeholders and the research teams (see *Table 1*).

Search methods for identification of studies

We comprehensively searched the literature to identify all relevant studies across all six senses: the terms used were based on prior searches[6] and the disorders identified by the research and stakeholder teams [see *Stakeholder activities (what happened)*, Activity 1 and *Report Supplementary Material 1*]. Search terms were drafted and refined by a stroke-specific information specialist (JC) and peer reviewed using current standards[119] (see *Appendix 1* for MEDLINE search terms and *Report Supplementary Material 9* for full searches).

Electronic searches

Electronic bibliographic databases and clinical trial registers were searched from inception (unless otherwise indicated) to 7 February 2020 including the Cochrane Stroke Group Register, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews (CDSR) in the Cochrane Library (2020, Issue 1), MEDLINE (Ovid; from 1996) and EMBASE (Ovid; from 1980) (see *Report Supplementary Material 9*).

Searching other resources

We also conducted an extensive search for published and unpublished studies, via:

- OpenGrey [www.opengrey.eu/ (accessed September 2022)]
- Grey Matters: a practical tool for searching health-related grey literature [www.cadth.ca/grey-matters-practical-tool-searching-health-related-grey-literature (accessed September 2022)]

- Google Scholar [https://scholar.google.com/ (accessed September 2022)]
- NIHR Clinical Research Network [www.nihr.ac.uk/explore-nihr/support/clinical-research-network.htm (accessed September 2022)]
- Physiotherapy Evidence Database (PEDro) [https://pedro.org.au/ (accessed September 2022)]
- OTseeker [www.otseeker.com/ (accessed September 2022)]
- PROSPERO International prospective register of systematic reviews [www.crd.york.ac.uk/prospero/ (accessed September 2022)].

National and international guidelines, government, HCP, relevant charities and patient support organisations websites were searched. Research, professional associations, foundations and experts in the field were also contacted (see *Report Supplementary Material 10*). An initial database search identified few paediatric studies. In consultation with a paediatric specialist (LD) and reflecting the iterative nature of scoping review searches, further sources specific to children were searched (see *Report Supplementary Material 10*). Forward citation tracking using Science Citation Index and Google Scholar was also completed (last searched 24 November 2020) together with searching reference lists of included studies.

Selection of studies

Applying selection criteria

Searches were imported into EndNote software (v8) and de-deduplicated.[120] Titles were screened for inclusion with ineligible titles or duplicates excluded (KMcG). Potentially relevant abstracts were independently screened using Covidence systematic review management system (KMcG, CH). Based on the inclusion criteria, abstracts were independently categorised as 'relevant', 'irrelevant' or 'unsure'. Studies ranked as irrelevant by both reviewers were excluded. The full text of the remaining studies was retrieved and assessed independently (KMcG, CH). Where disagreement occurred, or a study was categorised as unsure, an expert in that sensory area was consulted. Exclusion reasons were recorded and reported.[117]

Screening of grey literature or studies identified during supplementary searches was conducted by one researcher (KMcG, PC or CH) and key identifiers were entered into Microsoft Excel®. Details were checked by a second researcher.

Perception terminology and decision-making

Perceptual terminology is complex (see *PIONEER definition of perception*) and specific challenges we encountered in determining whether a study population had a perceptual disorder included:

- the lack of universal agreement on a definition of perception and the need to determine authors' precise meaning, and delineation between disorders of perception, sensation, attention and cognition
- differences in terminology between the senses, populations (adult and paediatric) and disciplinary fields.

Challenges were compounded by poor reporting of the disorder – both whether a study population had a perceptual disorder and whether an intervention addressed a perceptual disorder. Reviewers considered all relevant and available information, including reported details on type and location of stroke, the tools used to assess perceptual function and theoretical frameworks underpinning intervention design when distinguishing perceptual from other disorders. The key phrase 'distinguish, discriminate, recognise and interpret' from our coproduced definition [see *Stakeholder activities (what happened)*] supported the determination of whether a disorder reported related to perception or sensation: specifically, we sought evidence of processing of sensory information as opposed to simply detecting the presence or absence of sensory stimulation. Our research team and Clinical Expert Group specialists provided valuable third reviewer input as required in applying our inclusion criteria.

Data charting and categorising

Data extraction forms

Data extraction forms were developed in Microsoft Excel, based on the TIDieR checklist[97] and forms used in prior complex evidence syntheses. Data extraction forms were independently piloted (CH, KMcG) on five studies with different research designs, populations and interventions. Completed forms were then discussed and refined to ensure that all relevant data were extracted in an efficient manner. Data charting was completed (KMcG) and cross-checked (CH). Where studies included mixed populations, stroke-specific data were extracted where possible.

Data items extracted

We extracted the following data for each included study:

- Demographics: author, year of publication, type of publication, country.
- Design and methods: aim, design, number of recruitment sites, stakeholder involvement, participant numbers, withdrawals or lost to follow-up.
- Participant characteristics: age, sex (% female), stroke severity measurement, stroke type, hemisphere affected, other stroke-related impairment, time since stroke, inclusion of non-stroke survivors (*n*).
- Perceptual disorder: sense, diagnosis.
- Intervention and comparator characteristics: details extracted using the TIDieR checklist,[97] including number of interventions in the study, intervention approach, theory supporting the intervention, materials used, reporting of intervention procedure, who provided the intervention, mode of delivery, location, duration, single/multiple sessions, adaptation, other interventions tested, if usual care was provided.
- Assessed outcomes: outcome measures/tools for each eligible outcome; other outcomes specified and reported and data collection time points.
- Additional qualitative data: we planned to extract any descriptive themes relating to intervention effect/impact, costs or implementation, including the name and description of the content and meaning.[121]

Intervention categorisation

Selected data were categorised using drop-down menus within the data extraction form, to facilitate interpretation and maximise the clarity of reporting. Intervention categorisation was based on the underlying therapeutic approach and used an established approach.[32,33]

Interventions were categorised as:

- pharmacological – relating to the use of drugs
- surgical – relating to suture, incision, excision, manipulation or other invasive procedure that usually, but not always, requires local, regional or general anaesthesia[122]
- non-invasive brain stimulation (NIBS) – technologies and techniques used to modulate the excitability of the brain via transcranial stimulation (such as tDCS)[123]
- rehabilitation – designed to optimise functional ability and reduce disability in individuals with health conditions, in interaction with their environment.[124] Rehabilitation interventions were subcategorised as:
  - restitution (direct training of the impaired function)
  - compensation (via training to use a spared function)
  - substitution (use of an external device or modification)[125]
  - mixed (a combination of the above approaches).

Categorisation was undertaken by a researcher (KMcG), checked by a second (CH) with expert input as required (DG, SMH). See *Report Supplementary Material 11* for full list of data categorisation options.

Critical appraisal of individual sources of evidence

In keeping with scoping review guidelines,[117] we undertook no critical appraisal of included study quality, reflecting the scoping review aim of identifying and mapping available evidence.

Data synthesis

Collating and summarising the results

We collated the evidence identified in the scoping review into tables using the extracted and charted data.[94,95] Data were organised by study characteristics (design, year, continent), population (side of stroke, duration of stroke, sense affected, age, sex) and intervention (using TIDieR-based descriptors including approach, materials, who delivered, modality, location, duration, number of sessions, tailoring). The frequency of outcome measures across included studies was also tabulated. We created graphs and numeric summaries. Comparisons explored the nature and breadth of the findings, and identified key areas where data were poorly reported or absent. Results were discussed with the Lived Experience Group [see *Stakeholder activities (what happened)*].

Reporting the results

We created narrative data summaries[94] based on the following:

- The number and characteristics of included studies, study design, year of publication and country of origin.
- The participant population, including the details of their stroke and the senses affected.
- Intervention summaries were created reflecting the key TIDieR[97] checklist categories and grouped according to the sense affected.
- The nature and number of outcomes in each category were presented, noting gaps.

Interactive evidence gap mapping

A series of interactive evidence gap maps[116,126,127] provided a simple and accessible visual summary of the evidence using Tableau and Evidence for Policy and Practice (EPPI)-mapper software packages. Maps were shared with the Lived Experience Group to elicit their opinions, identify the most important information and how best to organise the information. Group members preferred a 2 × 2 matrix (in EPPI-mapper), which showed the relationship between the volume of evidence for an intervention category and the associated study outcomes. Group members recommended that the maps should be uncluttered, but sufficiently detailed to provide a legacy database, supporting future perceptual disorder research. Evidence gaps were highlighted.

Interpreting the findings

Our Clinical Expert and Lived Experience Groups informed our interpretation of the scoping review findings via online discussion [see *Stakeholder activities (what happened)* and *Report Supplementary Material 4*].

Summary

The scoping review aimed to identify all published and unpublished research evidence relating to interventions for perceptual disorders after stroke and to provide a comprehensive overview of the range, focus and nature of that evidence and in turn to highlight any evidence gaps. We used a systematic six-stage scoping review process to ensure rigour. Perception and perceptual disorder definitions were

agreed with our stakeholders. Our peer-reviewed search involved bibliographic databases and grey literature, with search terms created by an information specialist. Identified titles were screened by a reviewer, potentially eligible abstracts and full texts were independently screened by two reviewers, with topic-specialist input as needed. Data on study, participants, interventions and outcomes were extracted and categorised using Excel sheets. Data were tabulated and numerical and narratively summarised. Evidence maps displayed our findings and highlighted evidence gaps.

Chapter 5 Scoping review results

Introduction

In this chapter we report the scoping review findings, which aimed to provide a comprehensive overview of the scope, nature and gaps in the evidence relating to interventions for perceptual disorders.

Scoping review search results

Of 91,869 identified records, we removed duplicates, studies that did not meet inclusion criteria such as those based on a non-stroke population, no perceptual disorder intervention and ineligible design. We also excluded ongoing studies (*Figure 3*). A total of 80 relevant studies were identified (see *Appendix 2*).

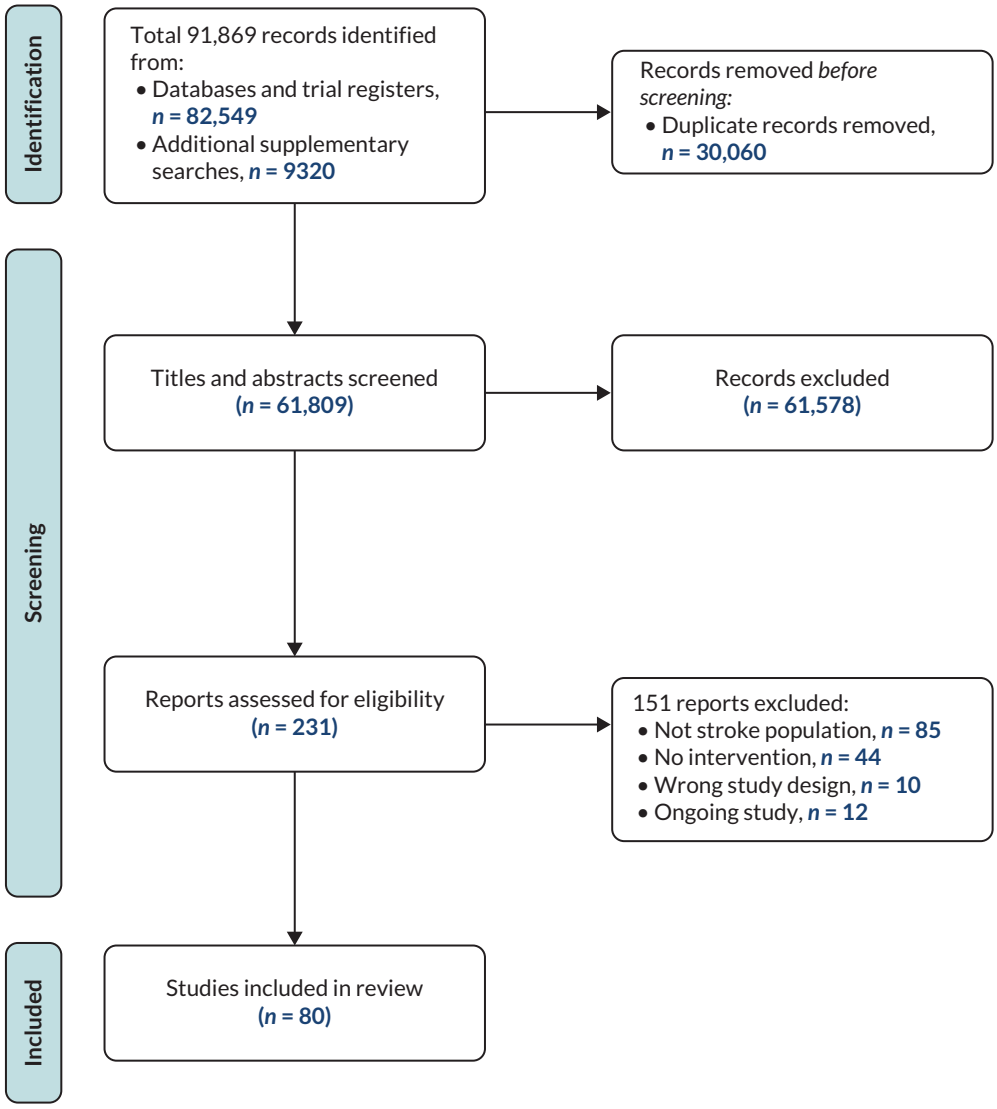

FIGURE 3 Preferred Reporting Items for Systematic Reviews and Meta-Analysis[128] diagram for scoping review literature identification. Note: figure is based on one published in *Stroke*.[112]
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Included studies

Design and location

Included studies were predominantly case reports (45%, 36/80) or RCTs (27.5%, 22/80) but also included N-of-1 designs (11.2%, 9/80), cohort studies (11.3%, 9/80) and controlled trials (2.5%, 2/80). No qualitative studies were included. Studies were conducted in Asia (33.8%, 27/80), Europe (32.5%, 26/80), North America (18.8%, 15/80), Australia (8.8%, 7/80) and South America (3.8%, 3/80). The setting for two studies (2.5%, 2/80) was not reported.

Recruitment

Few (41.2%, 33/80) reported recruitment data, perhaps reflecting the prevalence of single-participant studies (43.7%, 35/80). Only 5% (4/80) described recruitment over multiple sites.

Age of data

All 80 studies were published between 1973 and 2020: 34 (42.5%) in the last 5 years and 51 (63.8%) in the last 10 years. Most RCTs (12/22, 54.5%) were published between 2015 and 2020 (*Figure 4*).

Attrition

Where reported, participant withdrawal and loss to follow-up was low; 28 (35%) reported no withdrawal, 3 (3.8%) reported 1 withdrawal, 2 (2.5%) reported 2 withdrawals, 1 (1.3%) reported 4 withdrawals and 1 (1.3%) reported 7 withdrawals.

Stroke survivor or family involvement in research

Stroke survivor or carer involvement was not reported in any studies' design or implementation.

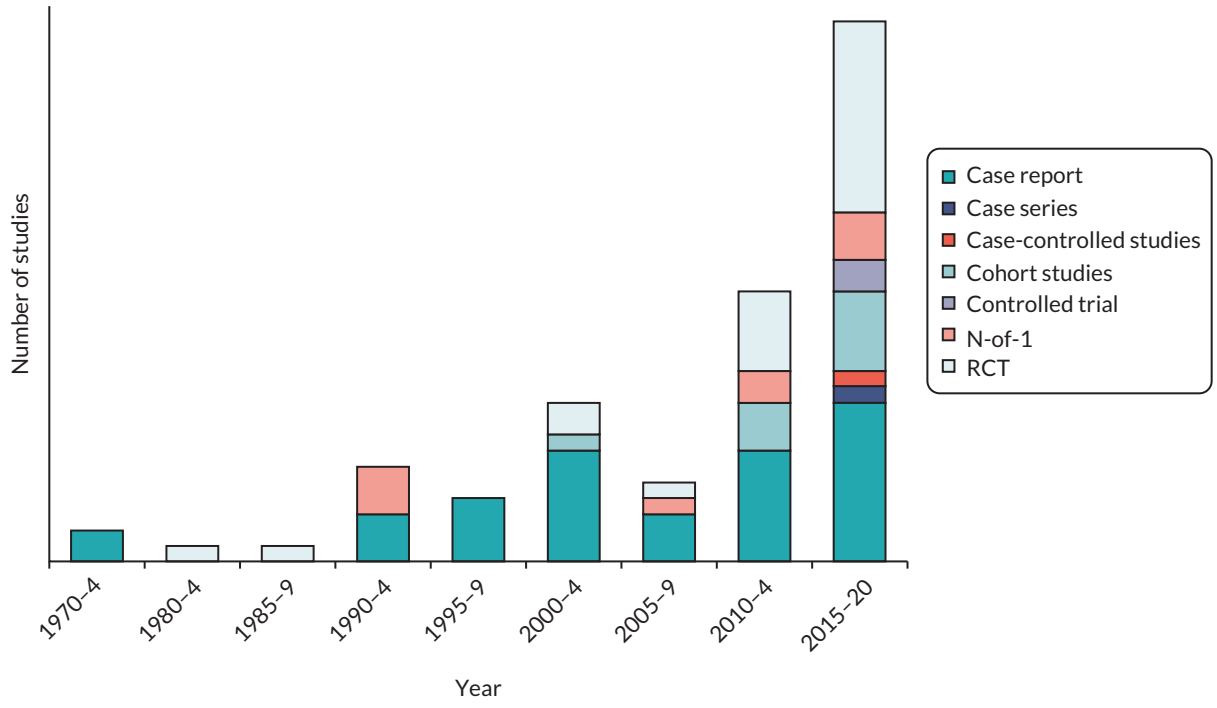

FIGURE 4 Studies included in the scoping review: study design and year of publication. Note: figure is based on one published in *Stroke*.[112]

Participants included

We included 80 studies (n = 922) in the scoping review. Eight studies recruited mixed participant populations: four recruited stroke survivors with and without perceptual disorders; four recruited participants with perceptual issues following stroke and other aetiologies. We were able to extract the data specific to those with perceptual disorder following stroke from five studies (n = 29), but this was not possible for data from three studies (n = 24) were more problematic. The scoping review data reflect information from 893 participants, of which 869 (97.3%) were stroke survivors with stroke-related perceptual disorders.

The largest sample size was 80 participants [median = 3.5, interquartile range (IQR) 1–16.5]. Most participants were recruited to RCTs (70.5%, 630/893). Thirty-five studies reported on only one participant.

Age

Most participants were adults with 53.8% (43/80 studies) 18 to 65 years, and 31.3% > 65 years (25/80 studies); 5 children (6.3%; < 18 years) were included in five individual case studies.

Sex

Fewer females were represented within included studies, with mean percentage across the studies of 34.8%. This was not observed to alter by age of the data set.

Stroke severity, lesion and concurrent impairments

Few studies reported stroke severity (16.3%, 13/80). Right hemisphere lesions were common [39/80 studies (48.8%) recruited > 60% participants with right-sided lesions]. This was most apparent for studies of somatosensory deficits with 64.2% studies having > 60% participants with right-sided lesions. Concurrent stroke-related impairments were noted in 51.3% (41/80) of studies; however, this was not reported in 49.3% (39/80) of studies.

Time since stroke

Stroke survivors were recruited across the stroke trajectory: acute (15.6%, 139/893), subacute (38.1%, 340/893) and the chronic phases (35.6%, 318/893).

Diagnosis

Perceptual disorders were diagnosed using standardised tests (79.2%, 707/893), clinical assessments (see *Included studies*; 47/893) or both (2.1%, 19/893). For 26 participants (2.9%) their diagnosis was based on a combined clinical assessment and self-report. Two further participants' perceptual disorder diagnosis was based on self-report (0.2%) while the method of diagnosis was unreported for 92 participants (10.3%, 92/893).

Perceptual disorders

Perceptual disorders described in the included studies were primarily visual (42.5%, 34/80) and somatosensory disorders (35%, 28/80). Few studies focused on auditory (8.7%, 7/80) or tactile (7.5%, 6/80) perceptual disorders. Only one study focused on taste and smell disorders, along with four other studies addressing a 'mixed perceptual disorders' category (6.2%, 5/80). The nature of the study design varied by sense addressed (*Figure 5*).

Studies conducted in Asia had a focus on somatosensation disorders (13/27, 48.1%); almost half of these studies were RCTs (six RCTs). In contrast, European studies most often described visual disorders (12/26, 46.1%) and frequently using case reports (seven case reports). Most somatosensory studies identified were recently published 71.4% (20/28) since 2015.

Visual perception

Stroke survivors with visual perceptual disorders accounted for 40% (357/893) of participants included in this review, across 34 studies (42.5%, 34/80); disorders included visual–spatial deficit (3.9%, 35/893), visual hallucination (including Charles Bonnet syndrome) (0.9%, 8/893), visual agnosia (0.3%, 3/893) or 'other' visual perceptual disorders (4.1%, 37/893). The largest group of participants were classed as experiencing a non-specific 'visual perceptual deficit' (30.6%, 274/893), which could include those with a mix of several perceptual issues, or diagnosis was based on perceptual test score, for example Motor-Free Visual Perception test (MVPT)[129] (*Figure 6*) that did not specify the nature of the disorder detected.

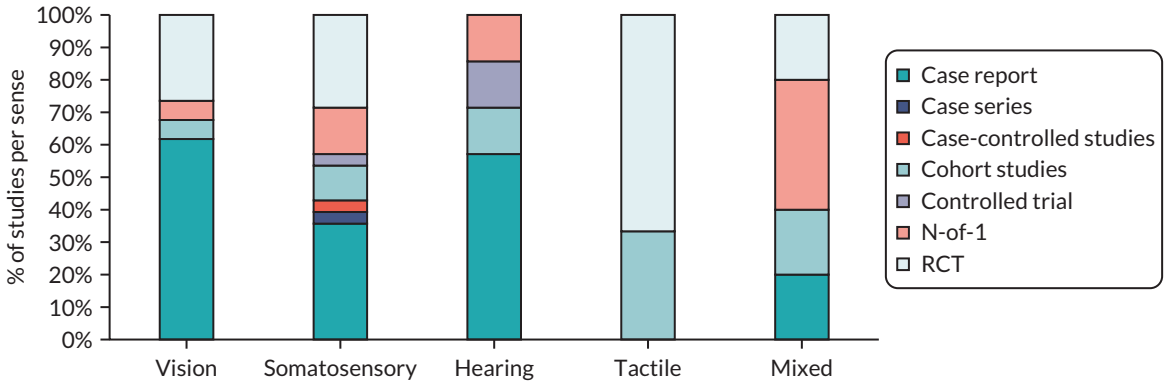

FIGURE 5 Scoping review findings by study design and sense (%). Note: figure is based on one published in *Stroke*.[112] Reproduced with permission from Hazelton *et al.*[112] This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The text below includes minor additions and formatting changes to the original text.

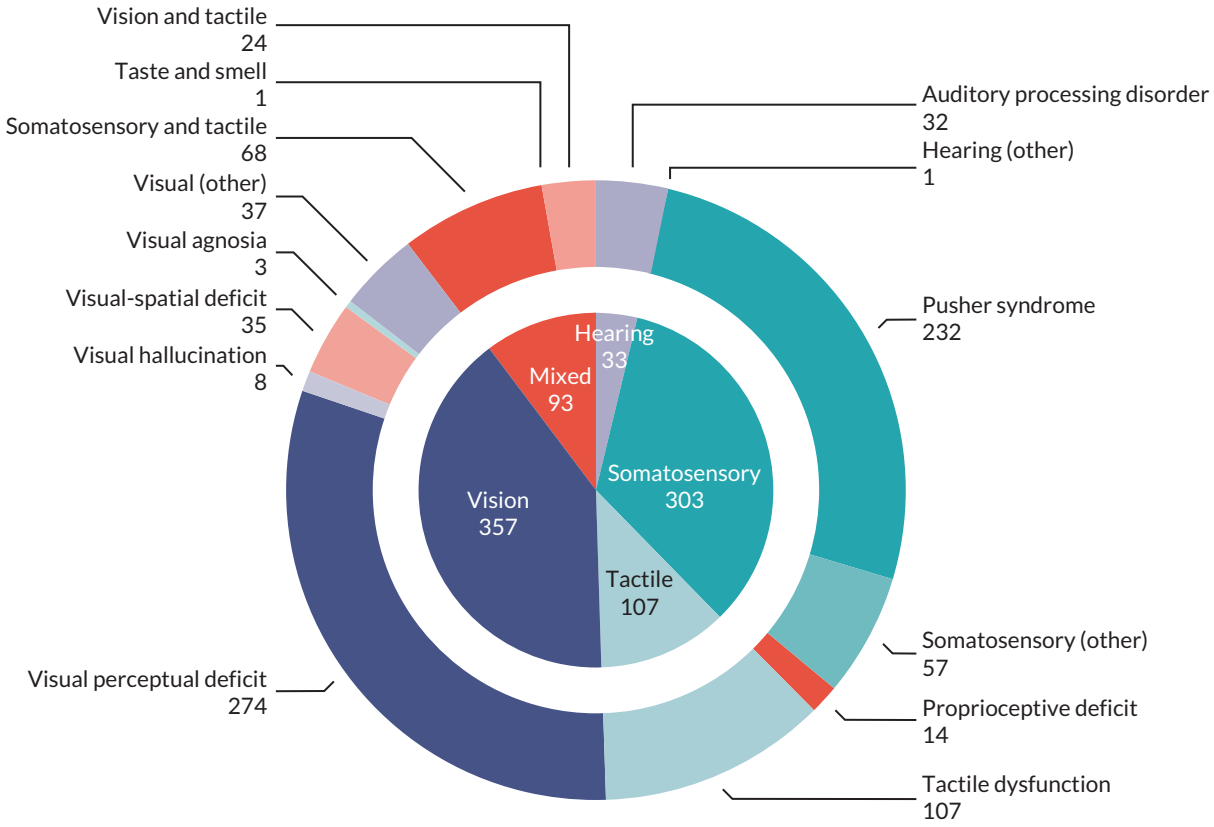

FIGURE 6 Included participants: by sense (inner ring) and perceptual disorder (outer ring). Note: figure is based on one published in *Stroke*.[112]
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Somatosensation

Somatosensation deficits were reported by a third of participants (33.9%, 303/893) across 28 studies (35%, 28/80). Disorders included Pusher syndrome (26%, 232/893), proprioceptive deficits (1.6%, 14/893) or were categorised as 'other' somatosensory disorder (6.4%, 57/893).

Auditory perception

Few studies (8.7%, 7/80) described participants with an auditory perceptual disorder. These were classed as either an auditory processing disorder (3.6%, 32/893) and/or hearing 'other' (0.1%, 1/893).

Tactile perception

All participants were reported to experience a form of general tactile dysfunction (12%, 107/893) across six studies (7.5%, 6/80).

Mixed perceptual disorders

Studies that recruited participants with perceptual disorders of two or more senses included participants with mixed tactile-somatosensory disorder (7.6%, 68/893), mixed taste–smell disorder (0.1%, 1/893) or mixed vision–tactile disorder (2.7%, 24/893).

Interventions

We identified 93 interventions across 80 studies. Rehabilitation interventions were common (83.9%, 78/93 interventions) and further classified as: restitution, substitution, compensation or a mixed rehabilitation approach (see *Intervention categorisation*). No surgical or assessment-based interventions were identified.

Nature of interventions

Intervention materials included technology based, HCP led and those using specialist equipment.

Technology-based interventions

Interventions that used technological devices such machinery, computers and robotic devices supported 28 interventions (30.1%) including electrical stimulation, vibration, computer games/software, gaming devices (e.g. WiiFit®) and robotic devices (e.g. Lokomat®). Rationale was provided for all but two (7%) interventions. The procedures used were reported for all but one intervention (3.6%) while access to intervention materials was reported in 20 studies (71.4%, 20/28).

Healthcare professional-led interventions

Thirty HCP-led interventions were described (32.3%, 30/93), commonly physiotherapists (36.7%, 11/30) or OTs (16.7%, 5/30). Example interventions include route training, training in ADLs, exercise provision and postural training. HCP-led interventions primarily addressed somatosensory or vision perceptual disorders but also included one auditory study. Rationale (90.0%, 27/30), procedural information (93.3%, 28/30) and information on how to access the intervention materials (66.6%, 20/30) were provided for most interventions.

Specialist equipment

Some tactile, somatosensory and mixed perceptual disorders interventions (14%, 13/93) used specialist equipment such as balance boards, tactile discrimination grids or sponges. All provide procedural details and an intervention rationale, with information on how to access materials reported for all but two interventions (84.6%, 11/13).

Mode of delivery

Most interventions were delivered one to one (81.7%, 76/93), with few self-managed (4.3%, 4/93) or delivered to a group (3.2%, 3/93). These details were unavailable for nine interventions (9.7%, 9/93) or were unclear (1.1%, 1/93).

Location

Interventions were delivered in a hospital inpatient (37.6%, 35/93), in or outpatient (21.5%, 20/93), or outpatient basis (1.1%, 1/93). Only three were home-based (3.2%, 3/93). A third of interventions did not report this detail (33.3%, 31/94).

Frequency

Interventions were often delivered over multiple sessions (72%, 67/93). Eight were delivered in a single session (8.5%, 8/93). For 17 interventions (18.3%) these details were unreported or unclear (1.1%, 1/93).

Duration

The included interventions lasted < 1 week (15.1%, 14/93), 1–4 weeks (30.1%, 28/93); 1–3 months (10.8%, 10/93) or > 3 months (4.3%, 4/93). Several studies did not describe the duration (34.4%, 32/93) or it was unclear (5.4%, 5/93).

Modification or tailoring of interventions

Information on tailoring of interventions to participants or any intervention modifications were not reported by approximately half the interventions identified (54.3%, 51/93). Tailoring (usually to initial ability or in relation to progress) was described for 12 interventions (12.8%) with a further 23 interventions (24.5%) stating there was tailoring, but no details were provided. For seven interventions, this information was unclear (7.4%).

Intervention fidelity

Most interventions did not refer to any fidelity measures (96.8%, 90/93) or the information provided was unclear (1%, 1/93). Three interventions described plans to measure intervention fidelity (3%, 3/93).

Some intervention details were rarely reported, and we found no report of the intervention procedure (10.8%, 11/93), provider (52.7%, 49/93) or duration (34.4%, 32/93). Most described an intervention rationale (76.4%, 71/93). Some described the delivery of experimental interventions alongside usual care (22.6%, 21/93), but this was not always reported (73.1%, 68/93).

Interventions targeting perceptual disorders

Interventions addressed five perceptual disorder domains: visual (39.7%, 37/93), somatosensory (30.1%, 28/93), hearing (5.7%; 7/93), tactile (7.5%; 7/93) and mixed perceptual disorders (5.7%, 7/93; *Figure 7*).

Visual perception disorder interventions

Of 37 visual perceptual disorder interventions, 31 had a rehabilitation focus (83.8%, 31/37), including restitution (48.4%, 15/31), mixed (25.8.1%, 8/31), compensation (12.9%, 4/31) and substitution interventions (3.2%, 1/31). Other intervention approaches were unclear (9.7%, 3/31) (*Table 2*).

Restitution approaches used technology (66.7%, 10/15; including interactive computer-based training of visual skills) and HCP-led interventions (33.3%, 5/15) including teaching compensatory skills in real-world simulation tasks, training of eye movements or completion of perceptual-based tasks. Compensatory approaches included intentional blinking, route and strategy training while substitution interventions included covering of one side of glasses with cardboard. One study used NIBS (Repetitive Transcranial Magnetic Stimulation – rTMS) for visual hallucination.

Pharmacological interventions identified (e.g. haloperidol, Librium and risperidone) targeted visual hallucinations and were described in single case reports with limited intervention details. Generally,

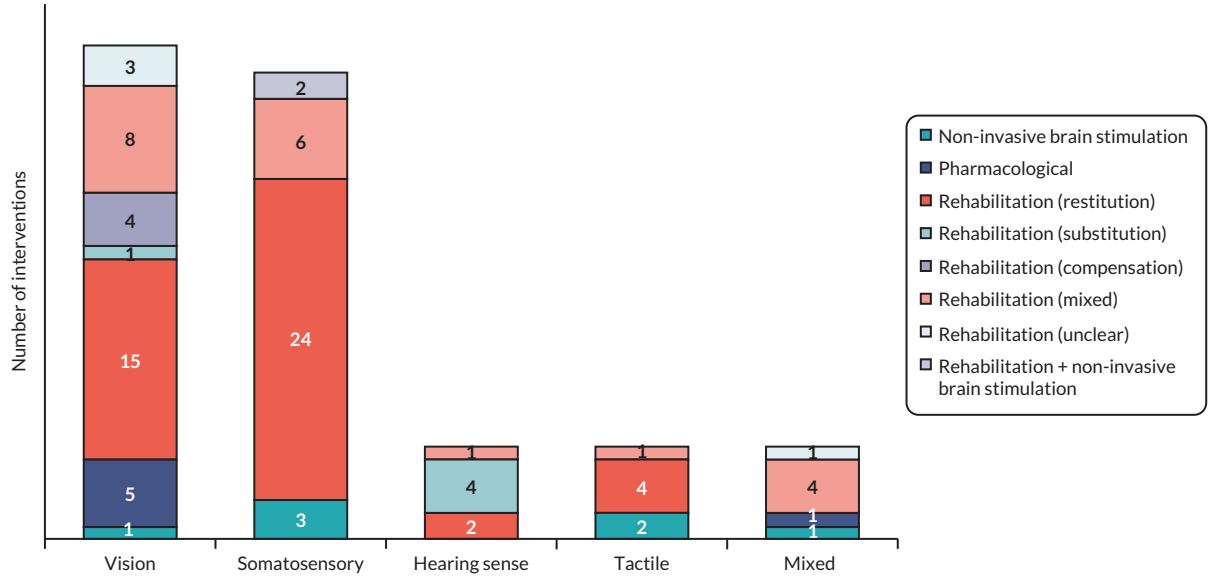

FIGURE 7 Perceptual disorder interventions by approach and sense. Note: figure is based on one published in *Stroke*.[112] Reproduced with permission from Hazelton *et al*.[112] This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The text below includes minor additions and formatting changes to the original text.

visual perceptual disorder studies lacked details on the intervention provider, location, intensity and duration.

Five case reports described mixed rehabilitation interventions for children with a visual perceptual disorder including specialist reading software and the development of strategies to overcome difficulties. Two interventions used a compensatory approach (route training and tutorial-based sessions). Where locations were reported they included school, home (using self-delivered tutorials) and inpatient settings.

Somatosensory disorder interventions

Four of the 35 interventions identified in the scoping review targeted somatosensory disorders and were categorised as rehabilitation (restitution 68.6%, 24/35; mixed 17.1%, 6/35), NIBS (8.6%, 3/35) and rehabilitation + NIBS (5.7%, 2/35) (*Table 3*). Most were HCP-led (48.6%, 17/35) and included postural control or reach training with weight-shifting exercises. Technology-based interventions (25.7%, 9/35) included robot-assisted gait training using the Lokomat device, postural training devices or gaming such as Nintendo Wii®. Interventions were predominantly delivered on a one-to-one basis (91.4%, 32/35), in an inpatient hospital setting (51.4%, 18/35), for 1 month or less (71.4%, 25/35).

Hearing perception disorder interventions

Seven interventions targeted hearing perceptual disorders, all of which adopted a rehabilitative approach (see *Table 4*). They were categorised as restitution (28.6%, 2/7), substitution (57.1%, 4/7) or mixed (14.3%, 1/7). Interventions were primarily technology-based (e.g. hearing aids 71.4%, 5/7) but also included HCP-led phonological therapy (14.3%, 1/7). The details of one intervention were unavailable (14.3%, 1/7). Where reported, all interventions were conducted on an individual basis (71.4%, 5/7) in a hospital setting (in/outpatient, 57.1%, 4/7) with one intervention (personal frequency modulated system) self-delivered at home (14.3%, 1/7) (*Table 4*).

Tactile perception disorder interventions

We identified seven interventions targeting tactile perception disorders which often involved a rehabilitation approach: restitution (57.1%, 4/7) or NIBS (28.6%, 2/7). Interventions included tDCS (28.6%, 2/7) or specialised equipment (57.1%, 4/7) such as texture grids, object recognition or sensory discrimination equipment. One intervention was technology-based (14.3%, 1/7) delivering vibrotactile

TABLE 2 Visual perceptual disorders: studies, participants and interventions

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Disorder addressed: Charles Bonnet syndrome						
Chen 2011[130] CR Taiwan	*N*: 1 Age: 70	NR 81–100%R	*Pharmacological* Quetiapine, then aripiprazole	Pharmacological Unclear/ 1-1 In/outpatient	5 mg Daily 21	3/52 21/365
Nakagawa 1999[131] CR China	*N*: 1 Age: 70	< 1 0–20%R	*Pharmacological* Dobutamine	Pharmacological Unclear 1-1 Inpatient	5 µg/kg/minutes NR NR	NR NR
Nguyen 2011[132] CR USA	*N*: 1 Age: 75	< 1 NR	*Pharmacological* Haloperidol	Pharmacological Medic 1-1 NR	NR Nightly NR	NR NR
Roberts-Woodbury 2016[133] CR NR	*N*: 1 Age: 69	1–6 NR	*Pharmacological* Risperidone	Pharmacological Unclear NR Inpatient	NR NR NR	NR NR
Disorder: other visual hallucination						
Cogan 1973[134] CR USA	*N*: 1 Age: 72	NR 81–100%R	*Pharmacological* Librium	Pharmacological Unclear NR NR	NR NR NR	NR NR
Flint 2005[135] CR USA	*N*: 1 Age: 64	NR 0–20%R	*Rehab (substitution)* Cardboard mask covering left side of glasses	Spec equipment Other Self-delivery NR	NR NR NR	Unclear NR
Poetter 2012[136] CR USA	*N*: 1 Age: 63	1–6 81–100%R	*Rehab (unclear)* Cognitive rehabilitation for neglect	NR NR NR Inpatient	NR NR NR	NR NR

TABLE 2 Visual perceptual disorders: studies, participants and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Rafique 2016[137] CR Canada	*N*: 1 Age: 30	> 6 months 81–100%R	*NIBS* rTMS using 70 mm diameter figure-of-eight coil and 1 Hz pulse at 85% of maximum output	NIBS NR 1-1 NR	30 minutes Daily 5	1/52 2.5/24
Disorder: visual agnosia						
Brunsdon 2017[138] CR Australia	*N*: 1 Age: 6	> 6 81–100%R	*Rehab (compensation)* Verbally mediated topographical orientation and route training	HCP-led Teacher 1-1 School	Unclear Unclear Unclear	12/52 Unclear
Tanemura 1999[139] CR Japan	*N*: 1 Age: 56	1–6 0–20%R	*Rehab (restitution and compensation)* Practical activities including sketching, wood carving, mosaic work and fishing	HCP-led NR 1-1 Inpatient	NR NR NR	NR NR
Zihl 2000 (4)[140] CR Germany	*N*: 1 NR	NR 0–20%R	*Rehab (restitution and compensation)* Stepwise training, including training of letter and feature recognition	Tech-based NR 1-1 Inpatient	45 minutes (2–4 per day) Unclear Unclear	NR NR
Disorder: visual perceptual deficit						
Mcdowell 2019[141] CR New Zealand	*N*: 1 Age: 16	> 6 0–20%R	*Rehab (compensation)* Detailed tutorial; strategy training including and emotional strategies	Other (Info) Other Self-delivery Home	NR NR NR	NR NR
Gottlieb 1991[142] CR USA	*N*: 1 Age: 80	< 1 0–20%R	*Rehab (compensation)* Intentional blink, gives temporary clarity	Other Other Self-delivery In/outpatient	NR NR NR	NR NR
Burr 1970[143] CR Australia	*N*: 1 Age: 74	1–6 81–100%R	*Rehab (restitution and compensation)* Training in ADLs via CCTV training footage	HCP-led OT 1-1 In/outpatient	NR NR Unclear	3/52 NR

continued

TABLE 2 Visual perceptual disorders: studies, participants and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Cho 2015[66] RCT South Korea	*N*: 27 Mean: (1) 62.9 (SD 7.2) (2) 63.6 (SD 9.3)	> 6 61–80%R	*Rehab (restitution)* Neurofeedback training, using computer-based games	Tech-based NR 1-1 Inpatient	30 minutes 5× week 30	6/52 15/24
Choi 2018[144] RCT South Korea	*N*: 28 Median: (1) 49.5 (IQR 2.3) (2) 51.0 (IQR 13.8)	> 6 61–80%R	*Rehab (restitution)* WiiFit training using Balance Board	Tech-based PT 1-1 NR	30 minutes 5× week 30	6/52 15/24
Dutton 2017[145] CR NR	*N*: 1 Age: 9	NR 0–20%R	*Rehab (restitution and compensation)* Training to detect, orient to and grasp visual stimuli to enlarge attentional visual field	NR NR NR NR	Half-day 5× week 5	NR NR
Edmans 1991[146] N-of-1 England	*N*: 4 Range: 54–65	1-6 0–20%R	*Rehab (restitution)* Training in ADL-type tasks	HCP-led OT 1-1 In/outpatient	45 minutes 3× week 12–21	4–7/52 9–16/24
Edmans 2000 [60] RCT England	*N*: 80 Mean: (1) 69.8 (SD 9.1) (2) 67.9 (SD 11.4)	> 6 41–60%R	*Rehab (restitution)* 'Transfer of training' rehabilitation	HCP-led OT 1-1 Inpatient	2.5 hours Unclear Unclear	6/52 15/24
			Rehab (compensation) 'Functional approach' rehabilitation	HCP-led OT 1-1 Inpatient	2.5 hours Unclear Unclear	6/52 15/24
Jo 2012 Cohort South Korea	*N*: 17 NR	> 6 61–80%R	*Rehab (restitution)* Computerised cognitive rehabilitation program	Tech-based OT 1-1 Inpatient	30 minutes 3× week 12	4/52 6/24

TABLE 2 Visual perceptual disorders: studies, participants and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Kang 2009[147] RCT South Korea	*N*: 16 Mean: (1) 59.5 (SD 10.7) (2) 62.5 (SD 9.6)	1–6 81–100%R	*Rehab (restitution)* Computerised visual perception rehabilitation	Tech-based OT 1-1 Inpatient	30 minutes 3 × week 12	4/52 6/24
			Rehab (restitution) Computer-based cognitive rehabilitation program	Tech-based OT 1-1 Inpatient	30 minutes 3× week 12	4/52 6/24
Kim 2011[148] RCT South Korea	*N*: 30 Mean: (1) 70.7 (SD 6.6) (2) 71.4 (SD 5.2)	1-6 NR	*Rehab (restitution and compensation)* Dynavision wall-mounted board user strikes when illuminated	Tech-based NR 1-1 In/outpatient	30 minutes 3× week 12	4/52 6/24
Zihl 2000 (3)[149] CR Germany	*N*: 3 Range: 58–61	0–20%R	*Rehab (restitution)* Eye movement training on slides/computer screen	Tech-based NR NR NR	45 minutes 3–4 per day Unclear	Unclear Unclear
Lincoln 1985[150] RCT England	*N*: 33 Mean: 50.1 (SD 15.1)	1–6 41–60%R	*Rehab (restitution)* Perceptual training tasks	HCP-led OT 1-1 Inpatient	60 minutes 4× week 16	4/52 16/24
Zihl 2000 (1)[151] CR Germany	*N*: 1 Age: 53	>6 0–20%R	*Rehab (restitution)* Computer-based hue discrimination training	Tech-based NR NR NR	NR NR NR	NR NR
Park 2015[152] RCT South Korea	*N*: 30 Mean: (1) 64.7 (SD 8.9) (2) 65.2 (SD 8.0)	1–6 NR	*Rehab (restitution)* Computer training including visual perception, attention, memory and orientation	Tech-based NR 1-1 In/outpatient	30 minutes 5× week 20	4/52 10/24

continued

TABLE 2 Visual perceptual disorders: studies, participants and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
O'Hare 1998[153] CR Scotland	*N*: 1 Age: 8	> 6 0–20%R	*Rehab (mixed)* Educational orthography with specialist reading software	Tech-based NR 1-1 Other (home/school)	NR NR NR	NR NR
Disorder: visual–spatial deficit						
Chen 2012[154] RCT USA	*N*: 11 Mean: (1) 73.8 (8.8) (2) 74.0 (8.4)	1–6 81–100%R	*Rehab (restitution)* Global processing training using Rey–Osterrieth figure	HCP-led NR 1-1 Inpatient	90 minutes Once 1	1/365 1.5/24
			Rehab (restitution) Rote repetition training using Rey–Osterrieth figure	HCP-led NR 1-1 Inpatient	90 minutes Once 1	1/365 1.5/24
Funk 2013[155] Cohort Germany	*N*: 13 Range: 23–60	1 to > 6 81–100%R	*Rehab (restitution)* Line presentation on computer screen with visual feedback	Tech-based NR 1-1 NR	NR 3× week 11	4/52 NR
Zihl 2000 (2)[156] CR Germany	*N*: 1 Age: 48	> 6 0–20%R	*Rehab (restitution)* Five-stage process progressing from table-top to PC activities	Tech-based NR NR NR	NR NR NR	NR NR
Towle 1990[157] N-of-1 England	*N*: 10 NR	NR 81–100%R	*Rehab (unclear)* Practicing perceptual tasks	NR Other (therapist) Group Inpatient	60 minutes 3× week 24	8/52 24/24
Disorder: visual – other						
Gillen 2003[158] CR Scotland	*N*: 1 Age: 10	> 6 0–20%R	*Rehab (mixed)* Adaptive compensatory approach to use strengths and abilities to compensate perceptual problem	HCP-led NR 1-1 Home	NR NR NR	NR NR

TABLE 2 Visual perceptual disorders: studies, participants and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Weinburg 1982[159] RCT USA	*N*: 35 Mean: (1) 64.2 (SD 9.0) (2) 66.8 (SD 9.8)	1–6 81–100%R	*Rehab (restitution and compensation)* Training to anchor attention and eye movements	HCP-led NR 1-1 In/outpatient	60 minutes 5× week 20	4/52 20/24
Zaharia-Pushkash 2010[160] CR Moldova	*N*: 1 Age: 67	NR 81–100%R	*Rehab (unclear)* Unspecified rehabilitation	NR NR NR NR	NR NR NR	NR NR

CR, case report; NR, not reported; *N*, number of participants; < 1, less than 1 month; 1–6, 1–6 months; > 6, more than 6 months; 1+, 1 year or more; SD, standard deviation; Spec equipment, specialist equipment; Tech-based, Machinery, computer and robotics; Unclear, information reported but not clear.

Note

Table is based on one published in *Stroke*.[112]

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TABLE 3 Somatosensation perceptual disorders: details of studies, population and interventions

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration/52 (weeks) /365 (days) /24 (hours)
Disorder: proprioceptive deficit						
Ko 2018[161] CC South Korea	*N*: 14 Mean: 65.2 (SD 7.8)	< 1 41–60%R	*Rehab (restitution)* Frankel's exercises	HCP-led PT 1-1 In/outpatient	15 minutes 5× week 15	3/52 3.45/24
Disorder: Pusher syndrome						
An 2019[75] RCT South Korea	*N*: 14 Mean: (1) 59.3 (SD 4.6) (2) 64.4 (SD 7.5)	< 1 81–100%R	*Rehab (restitution)* Game-based postural vertical training using whole-body tilt equipment	Tech-based NR 1-1 Inpatient	30 minutes td 5× week 30	3/52 15/24
			Rehab (restitution) Conventional postural vertical training using posture control training exercises	HCP-led NR 1-1 Inpatient	30 minutes td 5× week 30	3/52 15/24
An 2020[162] RCT South Korea	*N*: 30 Mean: (1) 60.5 (SD6.0) (2) 64.7 (SD6.9)	< 1 61–80%R	*Rehab (restitution)* Whole-body tilting postural training using a Spine Balance 3D	Tech-based PT 1-1 Inpatient	30 minutes td 5× week 30	3/52 15/24
			Rehab (restitution) General postural training using visual feedback and weight shifting	HCP-led PT 1-1 Inpatient	30 minutes td 5× week 30	3/52 15/24
Bergmann 2018[163] RCT Germany	*N*: 38 Mean: (1) 72 (SD 9) (2) 71 (SD 10)	1–6 61–80%R	*Rehab (restitution and substitution)* Robot-assisted gait training with Lokomat	Tech-based NR 1-1 Inpatient	60 minutes 5× week 8–10	2/52 8–10/24
			Rehab (restitution) Postural control training including sensory feedback	HCP-led PT 1-1 Inpatient	60 minutes 5× week 8–10	2/52 8–10/24

TABLE 3 Somatosensation perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration/52 (weeks) /365 (days) /24 (hours)
Broetz 2004[164] Cohort Germany	*N*: 8 Median: 63 (range: 51–79)	< 1 81–100%R	*Rehab (restitution)* Physiotherapy with visual feedback to demonstrate body orientation	HCP-led NR 1-1 Inpatient	30 minutes 6× week Unclear	Unclear Unclear
Freitas 2017[165] CR Brazil	*N*: 1 Age: 62.5	> 6 81–100%R	*Rehab (restitution)* Mirror therapy using balance and reach training	HCP-led NR 1-1 Outpatient	50 minutes 3× week 13	5/52 12.5/24
Fujino 2016[166] N-of-1 Japan	*N*: 3 Age: unclear	< 1 NR	*Rehab (restitution)* Relaxation therapy in prone position using treatment table	HCP-led NR 1-1 In/outpatient	10 minutes Daily 6	6/365 1/24
Fujino 2019[167] N-of-1 Japan	*N*: 2 Age: 69–75	< 1 81–100%R	*Rehab (restitution and substitution)* Electromyography-guided electrical stimulation therapy	Tech-based NR 1-1 NR	65 minutes Twice Unclear	2/365 2/24
Gillespie 2019[168] CR USA	*N*: 1 Age: 58	< 1 81–100%R	*Rehab (restitution and substitution)* Standing frame	HCP-led PT Group Inpatient	Unclear Unclear Unclear	18/52 6.5/24 (380 total minutes)
Jahn 2017[169] CR Germany	*N*: 1 Age: 81	1–6 81–100%R	*Rehab (restitution and substitution)* Spacecurl: suspension device with 3D rotation	Spec equipment PT 1-1 Inpatient	30 minutes 3× week 12	4/52 6/24
Jang 2018[170] CR South Korea	*N*: 1 Age: 67	< 1 81–100%R	*Rehab (restitution)* Rehabilitative therapy with movement therapy and somatosensory stimulation	NR NR 1-1 Inpatient	Unclear 5× week 80	16/52 Unclear

continued

TABLE 3 Somatosensation perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration/52 (weeks) /365 (days) /24 (hours)
Jokelainen 2000[171] CR Finland	*N*: 1 Age: 78	< 1 81–100%R	*Rehab (restitution)* Occupational therapy and physiotherapy rehabilitation programme	HCP-led PT 1-1 Inpatient	Unclear 5× week Unclear	Unclear Unclear
Kim 2016[172] Other South Korea	*N*: 10 Mean: (1) 63.1 (SD 12.3) (2) 62.4 (SD 14.9)	1–6 41–60%R	*Rehab (restitution and substitution)* Virtual reality visual feedback during Lokomat training	Tech-based NR 1-1 In/outpatient	30 minutes td 5× week 40	4/52 20/24
Lee 2017[173] N-of-1 South Korea	*N*: 3 Range: 58–65	1–6 NR	*Rehab (restitution)* Postural vertical training with/without visual feedback	HCP-led NR 1-1 Inpatient	60 minutes 3× week 18	6/52 18/24
Menghetti 2009[174] CR Brazil	*N*: 1 Age: 78	NR NR	*Rehab (restitution)* Aquatic physiotherapy using Bad Ragaz and Halliwick methods	HCP-led PT 1-1 Other (teaching clinic)	60 minutes 2×week 16	8/52 16/24
Mikolajewska 2012[175] CR Poland	*N*: 1 Age: 72	1–6 81–100%R	*Rehab (restitution)* Contraversive Pusher syndrome therapy including visual cues	HCP-led PT 1-1 NR	Unclear Unclear 10	2/52 Unclear
Pardo 2019[176] CS USA	*N*: 5 Range: 42–76	< 1 61–80%R	*Rehab (restitution)* Physiotherapy rehabilitation programme	HCP-led PT 1-1 Inpatient	90 minutes 5× week 19 average	4/52 28.5/24
Scheets 2007[177] CR USA	*N*: 1 Age: 76	NR 81–100%R	*Rehab (restitution)* Physiotherapy rehabilitation programme	HCP-led PT 1-1 Inpatient	25–45 minutes Daily 14	2/52 7/24
Voos 2011[178] CR Brazil	*N*: 1 Age: 65	> 6 81–100%R	*Rehab (restitution)* Physiotherapy including sensory stimulation, motor training and sensorimotor integration	HCP-led NR Unclear Home	60 minutes 2× week 48	24/52 48/24

TABLE 3 Somatosensation perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration/52 (weeks) /365 (days) /24 (hours)
Wang 2016[179] RCT China	*N*: 25 NR	NR NR	*Rehab (restitution)* Visual feedback via a dynamic and static balance/motion control system and balance board	Spec equipment PT Group In/outpatient	30 minutes 5× week 15	3/52 7.5/24
			Rehab (restitution) Core stability training using exercises	Spec equipment PT 1-1 In/outpatient	2 hours 5× week 5	1/52 10/24
			Rehab (restitution) Visual feedback and core stability exercises combined	HCP-led PT 1-1 In/outpatient	Unclear Unclear Unclear	Unclear Unclear
Yang 2015[180] RCT Taiwan	*N*: 12 Mean: (1) 62.4 (SD 12.9) (2) 57.6 (SD 17.3)	1–6 61–80%R	*Rehab (restitution)* Computer-generated interactive visual feedback training with Nintendo Wii balance board	Tech-based PT 1-1 NR	40 minutes 3× week 9	3/52 6/24
			Rehab (restitution) Mirror visual feedback training	HCP-led PT 1-1 NR	40 minutes 3× week 9	3/52 6/24
Yun 2018[181] RCT South Korea	*N*: 36 Mean: (1) 63.6 (SD 8.3) (2) 64.3 (SD 8.4)	1–6 0–20%R	*Rehab (restitution and substitution)* Robot-assisted gait training with Lokomat	Tech-based NR 1-1 In/outpatient	30 minutes 5× week 15	3/52 7.5/24
Babyar 2018[182] Cohort USA	*N*: 10 Range: 54–87	< 1 81–100%R	*NIBS* tDCS	NIBS NR 1-1 NR	15 minutes Once 1	1/365
			NIBS Galvanic vestibular stimulation	NIBS NR 1-1 NR	15 minutes Once 1	1/365

continued

TABLE 3 Somatosensation perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session details Length Frequency Number of sessions	Duration/52 (weeks) /365 (days) /24 (hours)
Krewer 2013[183] RCT Germany	*N*: 25 Range: 55–80	> 6 81–100%R	*NIBS and rehabilitation (restitution and substitution)* Galvanic vestibular stimulation with exoskeleton-assisted locomotion and physiotherapy	NIBS NR 1-1 Inpatient	20 minutes Unclear Unclear	Unclear Unclear
Nakamura 2014[184] N-of-1 Japan	*N*: 2 Range: 83–86	1–6 81–100%R	*NIBS and rehabilitation (restitution and substitution)* Galvanic vestibular stimulation with occupational therapy and physiotherapy	NIBS NR 1-1 Inpatient	20 minutes 5 days/week 10 with stimulation, 10 without	4/52 20/365
Disorder: somatosensory other						
Colombo 2015[185] CR Italy	*N*: 1 Age: 40	> 6 0–20%R	*Rehab (restitution and substitution)* 2-DOF elbow/shoulder manipulator and 1-DOF wrist manipulator	Tech-based NR 1-1 Inpatient	Unclear 2× per day Unclear	3.5/52
Jamal 2020[186] Cohort France	*N*: 32 Mean: 60.9(SD 10)	> 6 41–60%R	*Rehab (restitution)* Repetitive neck muscle vibration	Tech-based Researcher 1-1 NR	10 minutes Unclear	2/52 Unclear
Koo 2018[187] RCT South Korea	*N*: 24 Mean: (1) 58.7 (SD 3.4) (2) 52.4 (SD 3.2)	< 1 41–60%R	*NIBS* tDCS	NIBS Researcher 1-1 Inpatient	20 minutes Unclear Unclear	2/52 Unclear

CC, case controlled; CR, case report; *N*, number of participants; < 1, less than 1 month; 1–6, 1–6 months; > 6, more than 6 months; 1+, 1 year or more; DOF, degrees of freedom; NR, not reported; SD, standard deviation; Spec equipment, specialist equipment; Tech-based, Machinery, computer and robotics; Unclear, information reported but not clear; td, twice daily.

Note

Table is based on one published in *Stroke*.[112]

TABLE 4 Hearing, touch and mixed perceptual disorders: details of studies, population and interventions

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session detail Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Sense: hearing Disorder: auditory processing disorder						
Fifer 1993[188] CR USA	*N*: 1 Age: 60	< 1 81–100%R	*Rehab (substitution)* Wireless behind the ear contralateral routing of the signal hearing aid	Tech-based NR 1-1 NR	NR NR NR	8/52 NR
Koohi 2017 (1)[68] Cohort England	*N*: 9 Range: 24–78	1+ 41–60%R	*Rehab (substitution)* Speech in noise testing in sound-attenuating chamber with/without FM system	Tech-based NR 1-1 In/outpatient	NR NR NR	NR NR
Koohi 2017 (2)[189] CT England	*N*: 9 Range: 24–78	1+ 41–60%R	*Rehab (substitution)* Personal frequency modulated systems (Phonak iSense Micro receiver and Zoom link transmitter)	Tech-based Other Self-delivery Home	6 hours Daily 70	10/52 420/24
Papathanasiou 1998[190] CR England	*N*: 1 Age: 75	< 1 0–20%R	*Rehab (restitution)* Auditory discrimination of minimal pairs	NR Other 1-1 Inpatient	NR NR NR	NR NR
Woolf 2014[191] N-of-1 England	*N*: 11 Range: 44–81	> 6 NR	*Rehab (restitution and compensation)* Phonological and semantic-phonological therapy	HCP-led Other 1-1 NR	60 minutes 2× week 12	6/52 12/24
Zgaljardic 2013[192] CR USA	*N*: 1 Age: 39	1–6 0–20%R	*Rehab (substitution)* Augmentative and alternative communication devices	Tech-based NR NR In/outpatient	NR NR NR	10/52 NR

continued

TABLE 4 Hearing, touch and mixed perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session detail Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Sense: hearing Disorder: hearing other						
Fechtelpeter 1990[193] CR Germany	*N*: 1 Age: 41	NR 0–20%R	*Rehab (restitution)* Sound identification (everyday noises) and matching to cards	Tech-based NR 1-1 In/outpatient	NR NR 7 (Phase 1) and 10 (Phase 2)	NR NR
Sense: mixed senses Disorder: tactile and somatosensory (proprioceptive) deficit						
Carey 1993[194] N-of-1 Australia	*N*: 8 Range: 34–75	1–6 61–80%R	*Rehab (restitution and compensation)* Tactile discrimination and wrist proprioception training	Spec equipment NR 1-1 NR	NR NR NR	NR NR
Carey 2005[195] N-of-1 Australia	*N*: 5 Range: 44–60	1–6 0–20%R	*Rehab (restitution and compensation)* Transfer of training using texture grids, fabrics and proprioception stimuli	Spec equipment NR 1-1 NR	50 minutes 3× week NR	NR NR
	N: 5 Range: 47–88	1–6 41–60%R	*Rehab (restitution and compensation)* Stimulus-specific training of sensory discrimination, stimulus generalisation of sensory discrimination	Spec equipment NR 1-1 NR	NR NR NR	NR NR
Carey 2011[74] RCT Australia	*N*: 50 Mean: (1) 61.0 (SD 12.8) (2) 61.0 (SD 14.4)	> 6 41–60%R	*Rehab (restitution and compensation)* Sensory discrimination training using texture discrimination, limb sense and object recognition	Spec equipment NR 1-1 NR	60 minutes 3× week 10	3–4/52 10/24
			Rehab (unclear) Non-specific repeated exposure to tactile stimuli via grasping	Spec equipment NR 1-1 NR	60 minutes 3× week 10	3–4/52 10/24

TABLE 4 Hearing, touch and mixed perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session detail Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Sense: mixed senses Disorder: taste and smell hallucination						
Hayashi 2004[196] CR Japan	*N*: 1 Age: 55	< 1 81–100%R	*Pharmacological* Carbamazepine Valproate	Pharmacological Unclear 1-1 NR	NR NR NR	NR NR
Sense: mixed senses Disorder: visual and tactile disorder						
Oppenlaender 2015[197] Cohort Germany	*N*: 24 Median: 64 (range 42–84)	1–6 81–100%R	*NIBS* Galvanic vestibular stimulation	NIBS Researcher 1-1 NR	20 minutes NR 2	1/52 < 1/24
Sense: touch Disorder: tactile dysfunction						
Carey 2016[198] Cohort Australia	*N*: 11 Range: 40–79	NR 21–40%R	*Rehab (restitution and compensation)* Touch discrimination intervention: use of three texture grids with varying stimulus difficulty Explore and discriminate the odd texture	Spec equipment NR 1-1 NR	45–60 minutes 3× week 18	6/52 13.5–18/24
Enders 2013[199] Cohort USA	*N*: 10 Mean: 60 (SD 9)	NR NR	*Rehab (restitution)* Vibrotactile noise: monofilament and two-point discrimination with and without noise	Tech-based NR 1-1 NR	2 hours (noise 1 minute) Once 1	1/52 2/24
Fujimoto 2016[200] RCT Japan	*N*: 8 Mean: 61.6 (SD 9.0)	> 6 61–80%R	*NIBS* tDCS with tactile stimuli	NIBS NR 1-1 NR	15 minutes Once 1	NR < 1/24

continued

TABLE 4 Hearing, touch and mixed perceptual disorders: details of studies, population and interventions (*continued*)

Study ID (author, year) Design Country	Population Number Age (years) (1) (2) refer to participant groups within studies	Stroke Time post stroke %R hemisphere	Intervention Approach Description	Delivery Materials Who How Where	Session detail Length Frequency Number of sessions	Duration /52 (weeks) /365 (days) /24 (hours)
Kim 2015[201] RCT South Korea	*N*: 30 Mean: (1) 54.7 (SD 3.1) (2) 59.4 (SD 8.6) (3) 56.4 (SD 11.9)	> 6 21–40%R	*Rehab (restitution)* Pressure sense perception training on stable surface	Spec equipment PT 1-1 In/outpatient	30 minutes 3× week 12	4/52 6/24
			Rehab (restitution) Pressure sense perception training on unstable surface	Spec equipment PT 1-1 In/outpatient	30 minutes 3× week 12	4/52 6/24
Kitisomprayoonkul[202] 2012 RCT Thailand	*N*: 20 Mean: (1) 54.7 (SD 8.6) (2) 58.0 (SD 11.9)	< 1 NR	*NIBS* tDCS	NIBS NR 1-1 In/outpatient	20 minutes Once 1	1/52
Morioka 2003[203] RCT Japan	*N*: 28 Mean: (1) 61.3 (SD 11.0) (2) 62.6 (SD 13.3)	1–6 61–80%R	*Rehab (restitution)* Hardness discrimination exercise: discriminate hardness of sponge rubber placed under foot	Spec equipment NR 1-1 Inpatient	NR 5× week 10	2/52 NR

CC, case controlled; CR, case report; NR, not reported; CC, case controlled; n, number of participants; < 1, less than 1 month; 1-6, 1-6 months; > 6, more than 6 months; 1+, 1 year or more FM, frequency modulation; PT, physiotherapist; SD, standard deviation; Spec equipment, specialist equipment; Tech-based, Machinery, computer and robotics; Unclear, information reported but not clear; td, twice daily.

Note

Table is based on one published in *Stroke*.[112]

noise. Physiotherapists provided two interventions (28.6%, 2/7) but most providers were unreported (71.4%, 5/7). All interventions were delivered on an individual basis.

Mixed perception disorder interventions

Studies that recruited stroke survivors with perceptual disorders across more than one sense described seven interventions to address tactile and proprioceptive deficits (71.4%, 5/7) including specialised tactile and proprioceptive training equipment, such as texture grids and proprioceptive stimuli. Interventions were delivered on an individual basis, but few other details were available such as provider, location or duration. One study (14.3%, 1/7) explored the use of NIBS for a visual and tactile perceptual disorder, while another pharmacological study addressed complex taste/smell hallucinations by prescribing carbamazepine and valproate; no other details were provided.

Outcome measurements

The studies identified in the scoping review reported perceptual function (75%, 60/80), motor/sensorimotor (40%, 32/80), ADLs (22.5%, 18/80) and sensation outcome measurement (15%, 12/80) (*Table 5*). We also noted a few language-based outcome measures, which had not featured in our prioritised list. Other outcomes of interest such as discharge destination, economic outcomes, feasibility and acceptability, impact on family, friends and carers, impact on rehabilitation, measures of education and development, psychological well-being and mental health, QoL, social activity and participation were not reported.

Outcomes were measured at various time points; immediately post intervention (38.8%, 31/80); ≤ 1 month post intervention (11.3%, 9/80); 1–3 months post intervention (11.3%, 9/80); > 3 months post intervention (12/80; 15.0%).

TABLE 5 Number of studies reporting specific outcome measure domains

Outcome category	Hearing	Somato-sensation	Tactile	Vision	Mixed	Total
Perceptual function	4	24	6	22	4	**60**
Motor/sensorimotor ability		21	2	9		**32**
ADLs	1	12		5		**18**
Sensation		4	2	6		**12**
Cognition		1		8		**9**
Mobility, navigation and safety		3	1	1		**5**
Neurological function		2	1	1		**4**
Language	2			2		**4**
Adverse events		1	1	1		**3**
EADLs		1		1		**2**
Attention		2				**2**

Note
Table is based on one published in *Stroke*.[112]
Reproduced with permission from Hazelton *et al.*[112] This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The text below includes minor additions and formatting changes to the original text.

Mapping of data

Interactive visual maps provided a visual overview of the availability of evidence across the six sensory domains and intervention approach. These are available from www2.gcu.ac.uk/hls/PIONEERmap.html (accessed November 2022) (see example in *Figure 8*). Data were stratified by age (child vs. adult). The bubble size reflects the magnitude of the evidence (larger indicates more); the relevant abstracts will then be visible (where available) if the bubble is clicked. The empty cells reflect the evidence gaps.

The Lived-Experience Group feedback on the maps was positive

> *… it's probably the one of the first charts that I have understood quite easily. I've been able to see it all and it's very simple. … here you can see immediately that where the gaps are…I think that's really, really good. I love that. It's just very disheartening to see that nobody is doing anything about hearing, smell and taste.*
>
> *Lived Experience Group member*

Interpretation of scoping review results

The Lived Experience and Clinical Expert stakeholders discussed the scoping review results [see *Stakeholder activities (what happened)*, Activity 3 and *Report Supplementary Material 4*] and raised the following issues:

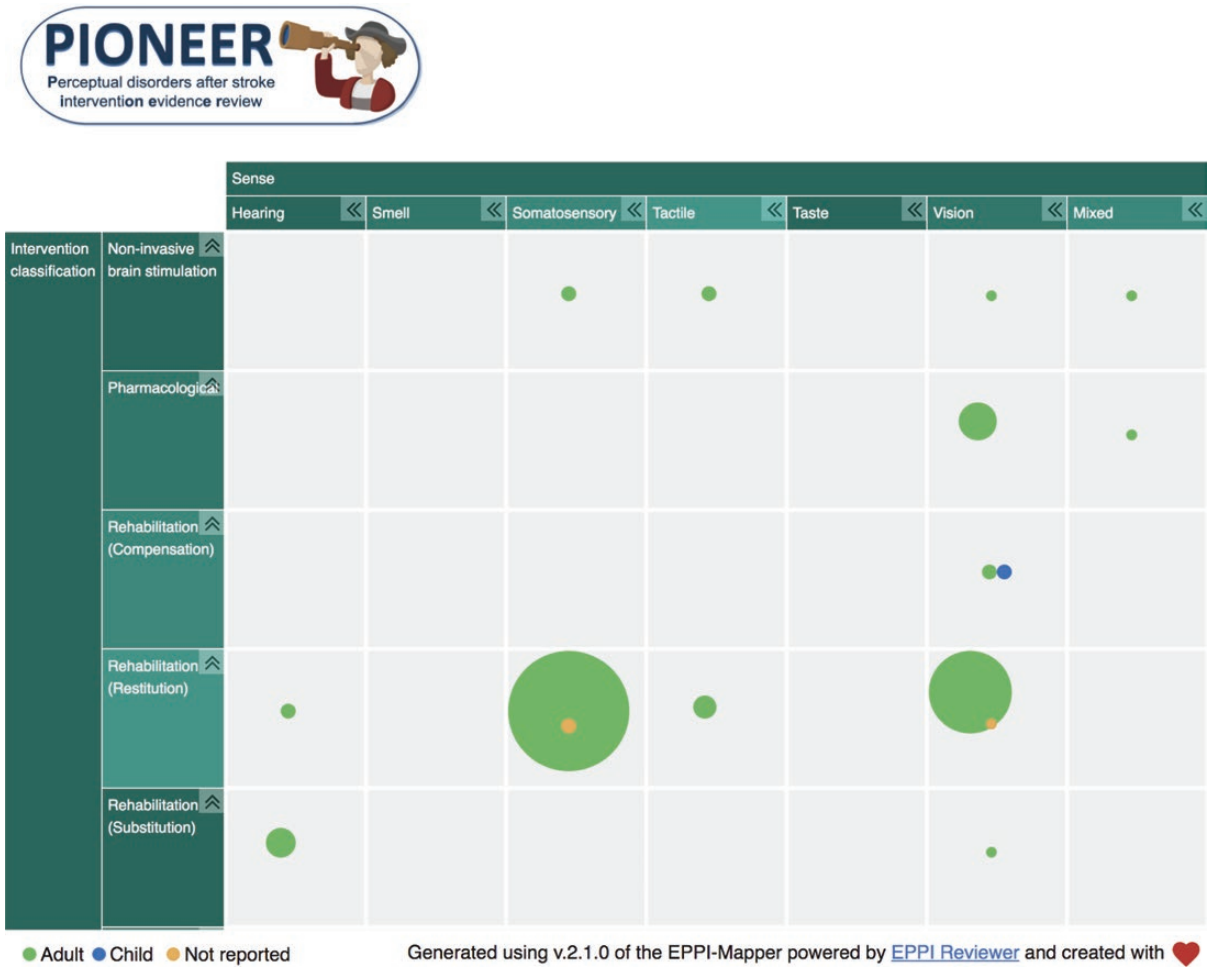

FIGURE 8 Interactive evidence map.

- There has been little high-quality research relating to perceptual problems after stroke, especially when compared to the amount and quality of research into other stroke-related impairments.
- The lack of high-quality research in this area demonstrated a lack of awareness and understanding about perceptual problems after stroke, and that this was associated with a lack of support and information for stroke survivors and carers.
- It is important to be aware that long-term recovery from perceptual problems is possible, rather than just in the first few months, and research should reflect this.
- The high number of case reports identified in the scoping review may reflect need for interventions to be tailored to individual patients. The resultant heterogeneity/complexity in intervention approach and thus lack of standardised interventions may make research in this field challenging and may impact on the development of research relating to perceptual problems.
- Better reporting would facilitate learning from research, including from individual case reports.
- Most studies delivered interventions in hospital settings, but there is a need for research into interventions/strategies to support people living at home.
- There were no qualitative studies which explored stroke survivor or carer experience, and no reported stakeholder involvement in studies. These were important gaps.
- There had been more research relating to visual and somatosensory perceptual problems than for other senses (hearing, tactile, taste or smell). Stakeholders felt that this may reflect a lack of awareness of problems relating to the other senses.

Summary

Our scoping review identified 80 studies (1970–2020) that typically used a case report or RCT design to predominantly investigate visual or somatosensory perceptual disorders. Interventions (n = 93) were often rehabilitative in approach and focused on improvements in the impaired function. Many interventions included direct training by an HCP, technology-based devices or specialist equipment. Interventions were often hospital-based, lasting up to 4 weeks with few reporting longer-term outcomes. Perceptual and motor/sensorimotor outcomes were most reported.

Important evidence gaps were identified, including a paucity of evidence relating to interventions addressing hearing, taste, touch and smell perceptual disorders post stroke and interventions developed to address perceptual disorders experienced by children. Key participant and intervention details were often unreported. In addition, qualitative studies exploring the experience of perceptual interventions and involvement of stroke survivors and carers as stakeholders were not identified, with a clear focus on quantitative designs.

Chapter 6 Cochrane systematic review methods

Introduction

This chapter describes the Cochrane systematic review methods used to synthesise and appraise high-quality RCT evidence of the clinical and cost-effectiveness of interventions for perceptual impairments after stroke. The findings of the systematic review are reported in *Chapter 7*. The review has been published in the CDSR.[204]

Our Cochrane systematic review 'Interventions for perceptual disorders following stroke' is an expanded update of a previous Cochrane systematic review from 2011 'Non-pharmacological interventions for perceptual disorders following stroke and other adult-acquired, non-progressive brain injury'.[6] Following approval by the Cochrane Stroke Group (personal communication 20 November 2019), we made several a priori revisions and adjustments to the methods, as follows:

- **Participant eligibility criteria**: our Cochrane Review focused on stroke populations. The 2011 review's inclusion criteria included participants with 'other adult-acquired, non-progressive brain injury'.
- **Intervention eligibility criteria**: we included all healthcare interventions (including pharmacological). The 2011 review[6] included non-pharmacological approaches only.
- **Search strategy**: we updated and expanded the search terms to cover a broad range of perceptual impairments across several senses: hearing, smell, somatosensory, taste, tactile and vision. The search informing the 2011 review was last updated in August 2009 and focused on visual perceptual disorders.
- **Use GRADE[98] and TIDieR[97]**: reflecting systematic review methodological advances, we used TIDieR checklist headings to support intervention data extraction and description and rated the certainty of evidence synthesis using GRADE.
- **Primary and secondary outcomes**: the outcomes considered in our review reflected stakeholders' outcome priorities.
- **Title**: we also adjusted the review title to reflect the changes above to 'Interventions for perceptual disorders following stroke'.

Our scoping review sought evidence related to stroke survivors of any age but identified no RCTs relevant to a paediatric population (see *Visual perception disorder interventions*), a finding supported by an earlier guideline.[87] Thus, our Cochrane Review focused on adult participants.

Research questions

Our systematic review considered three research questions:

1. Are interventions for perceptual deficits after stroke more effective than control, placebo, standard care or no intervention?
2. Is one intervention for perceptual deficits after stroke more effective than another intervention?
3. Are interventions more effective at improving outcomes in stroke survivors with specific demographic variables?

Criteria for considering studies for this review

The Cochrane systematic review inclusion criteria mirror those of the scoping review (see *Chapter 4*, *Criteria for considering studies for this review*), with three changes:

- **Types of studies:** we included RCT designs only.[205] In the case of crossover RCTs, we analysed data from baseline to the point of crossover. We included RCTs in which a comparison was made between an active treatment group that received an intervention for a perceptual disorder, to a group that received (1) no treatment, (2) a control intervention (placebo, standard care, attention control) (*Table 6*) or (3) an alternative perceptual intervention.
- **Types of participants:** we included only adult participants (18 years and older) with impaired perception following stroke.
- **Outcome measurements:** in comparison to the outcome measurements, we extracted in the scoping review (see *Chapter 4*, *Criteria for considering studies for this review*), we took forward a selection of these in the Cochrane Review (see *Outcome measures*).

Outcome measures

The outcome measures included in this review reflect those prioritised by our stakeholders [see *Stakeholder activities (what happened)* and *Types of outcome measures*]. The full list of outcomes was discussed by the research team to select those of most relevance to the Cochrane Review questions, considering Cochrane reporting guidance, clinical practice and data availability [based on the scoping review (see *Outcome measurements*)]. We selected a primary outcome measure (see *Primary outcome*) and five secondary outcome measures (see *Secondary outcomes*); this did not include any outcomes of feasibility or cost-effectiveness.

Primary outcome

Activities of daily living post intervention ('immediate' time point) was our primary outcome. We also extracted ADLs at a 3-month post-intervention follow-up point.

We included any validated standardised ADLs measure such as the Barthel Index,[210] Functional Independence Measure,[211] Modified Rankin Scale,[212] Katz Index of Activities of Daily Living,[213] Assessment of Motor and Process Skills[214] and Rehabilitation Activities Profile.[215]

Where data on more than one ADLs outcome measurement instrument were available in a RCT, we extracted and analysed the measure occurring earliest in the above list.

TABLE 6 Cochrane systematic review intervention comparator definitions

Comparator	Definition
No treatment	Where no intervention targeting the perceptual disorder(s) was received by the comparison group, compared to the active intervention group (e.g. a waiting list control group with delayed treatment until after the intervention period)
Placebo	An intervention that appears similar to, but omits a key therapeutic element of, the perceptual intervention or procedure under investigation (also described as 'sham' interventions)[206]
Standard care (usual or conventional care)	An intervention that reflects the usual care in that region and at that time point before the trial start for a given perceptual disorder (Faltinsen 2019)[206]
Attention control	An intervention that provides similar levels of trial contact and professional attention, and confers benefits of trial participation and expectations in the absence of active intervention components[207–209]

Secondary outcomes

1. EADLs as captured by outcome measurement instruments, for example Frenchay Activities Index.[216]
2. QoL:
   - QoL for example EuroQol-5 Dimensions (EQ-5D).[217]
   - Social activities and participation for example Australian Community Participation Questionnaire.
   - Mobility, navigation and safety for example Rivermead Mobility Index.[218]
3. Psychological well-being and mental health:
   - Stroke survivors, for example Hospital Anxiety and Depression Scale.[219]
   - Family, friends and carers, for example The Carer Strain Index.[220]
4. Perceptual function, for example Rivermead Perceptual Assessment Battery.[221]
5. Adverse events, for example fall, death, fatigue, accident rates.

Data were extracted for the time point immediately after intervention delivery; measures available at follow-up time points were recorded, but data not extracted.

For further details and examples of outcome measure tools, see *Report Supplementary Material 12*.

Search methods for identification of studies

The initial stages of the search strategy were described earlier (see *Chapter 4*, *Search methods for identification of studies*); all RCTs included in the scoping review were taken forward to the study selection stage (see *Study selection*). This was followed by two further search procedures:

1. To ensure identification of RCTs published since the scoping review's last search date, we updated our electronic searches, with the addition of a RCT study design filter to reflect narrower Cochrane Review inclusion criteria [last search 9 August 2021; *Appendix 3* for example search (MEDLINE); *Report Supplementary Material 13* for full searches].
2. We reviewed RCTs from the 2011 review.[6]

Reference lists of included RCTs were searched and forward citation tracking (Science Citation Index) and Google Scholar was completed for all included RCTs.

Data collection

Study selection

Once database searches were updated, duplicates were excluded, as were titles unrelated to stroke and perception (KMcG/KT). Two researchers independently considered the abstracts for remaining records (CH, KMcG/KT), excluding any that did not meet the inclusion criteria. Full texts for all potentially relevant studies were independently assessed by two reviewers (CH, KMcG/KT), as well as full-text reports of all RCTs identified in the scoping review and the historical Cochrane Review[6] were appraised. Disagreements relating to abstract or full-text inclusions were resolved through discussion, involving a third reviewer or relevant clinical specialist stakeholder where required. Reasons for exclusion were recorded.

Data extraction and management

Two piloted data extraction forms were used containing the data and categorisation variables (see *Data charting and categorising*) and detailing comparison(s) and outcomes measurement data. One reviewer extracted the data, which was checked by a second (KMc/KT/CH). For RCTs identified subsequent to

the scoping review, the data were extracted directly into Revman (KT) and independently checked by a second reviewer (CH): The variables extracted were:

- **Study:** country, setting, year, design, number of centres, number of randomised groups classified as (active intervention/no treatment/control).
- **Methods:** randomisation method, prospective power calculation, use of intention-to-treat analysis, recruitment, dropouts.
- **Participant:** inclusion criteria, exclusion criteria, number, age, sex, stroke details (type, time since stroke, hemisphere affected, severity), perceptual disorder, sense(s) affected and method of diagnosis, severity, presence of other stroke-related impairment.
- **Intervention:** intervention approach (rehabilitation/NIBS/pharmacological/surgery/assessment and screening). Rehabilitation interventions subclassification (restoration, compensation or restitution, or a combination; see *Intervention categorisation*). Invention materials, procedures, provider, mode, location, session and duration details, tailoring and modification.[97]
- **Outcomes:** outcome measurement instrument, measurement taken, time point and final value scores. Dichotomous data: participant numbers who experienced the event in each group. Continuous data: means and standard deviations (SDs) by group.

Two review researchers (CH/KMcG/KT) independently classified all intervention approaches, seeking input from a third (DG/SH) where differences were unresolved through discussion.

For RCTs that randomised a mixed stroke/non-stroke or perceptual disorder/non-perceptual disorder subpopulations, we planned to extract the stroke-specific data wherever possible. Where this was unavailable, we used mixed population data if > 80% were stroke survivors with a perceptual disorder. We planned to conduct sensitivity analyses to investigate the effect of including these data.

Where data were unavailable, we calculated it from the available values.[222] For all outcomes, we recorded any significance test, *t*, *f*, *p* values and direction of findings. If a RCT provided data on more than one of the primary outcome measurement instruments, we extracted them in the order described above (see *Primary outcome*). Where a RCT reported more than one outcome measurement instrument relating to a single outcome previously unidentified, data on the measurement instrument's validity and reliability were sought and compared, in consultation with a clinical expert in the relevant topic area, to choose the order of preference. This process did not consider the volume of data captured.

Data analysis

Risk of bias

Using the Cochrane ROB-1 tool we considered risk of bias.[223] Two reviewers (CH/KT) independently appraised included RCTs, grading the following risks:

> **Random sequence generation (selection bias):** *The method used to generate the random sequence was noted and judged whether it should produce comparable groups.*
>
> **Allocation concealment (selection bias):** *The method used to conceal the allocation sequence was noted, and we considered whether intervention allocation could have been foreseen before or during enrolment.*
>
> **Blinding (performance bias, detection bias):** *The measures used to mask RCT participants, researchers and outcome assessors from knowledge of allocation was noted, alongside any data on the measure's effectiveness, and used to determine the degree to which blinding was achieved.*

Incomplete outcome data (attrition bias): *The completeness of data for each main outcome was noted, including attrition and exclusions from analyses, participant numbers in each intervention group (compared with total randomised), reasons for attrition or exclusions and any re-inclusion in analyses.*

Selective reporting (reporting bias): *The outcome measurement instruments, and the reported data were compared to identify missing data. Trial protocols were used where possible.*

Other bias: *We noted any other concerns about bias.*

Risks of bias were categorised as high, low or unclear, with the reasons for decisions reported. Judgements for performance bias and detection bias were combined for reporting. If these differed, then the decision protocol was that (1) if low and unclear the overall category was labelled as unclear and (2) if high and low/unclear the overall category was considered as having a high risk of bias.

Data synthesis

The pre-specified comparisons for disorders in each sense (hearing, smell, somatosensation, tactile, taste and vision) were:

- *active intervention* for perceptual impairment versus *no treatment*;
- *active intervention* for perceptual impairment versus *control* (attention control/standard care/placebo).

We stratified the analysis according to intervention approach category (rehabilitation/NIBS/surgery/pharmacology/assessment and screening).

We also compared active interventions directly, where it was considered meaningful to do so. Decisions to do so were made following discussions among the research team, using tabulated data on the relevant RCTs.

Subgroup analysis and investigation of heterogeneity

We planned to consider a priori subgroup analyses where 10 or more RCTs were included in a single analysis,[224] based on:

- Treatment approach: rehabilitation, NIBS, surgery, pharmacology, assessment and screening.
- Participants: age (younger 18–65 compared to older adults > 65); male versus female.
- Stroke severity, time since stroke.

Sensitivity analysis

We planned sensitivity analyses on the primary outcome to explore the risk of bias and publication type (peer-reviewed publication, or other publication types such as conference abstracts, or unpublished reports). Where possible, we planned to explore the effect of selectively including RCTs which were at 'high' or 'unclear' risk.

Measures of treatment effect

Review Manager software (RevMan 5.4) supported the statistical analyses to determine treatment effects, using a random-effects model throughout. For dichotomous variables we planned to calculate a Peto odds ratio with 95% confidence intervals (CIs); for continuous data calculated the mean difference (MD) (for measurements in the same scale) and standardised MDs (for measurements in different scales) and 95% CI. We treated ADLs and other ordinal scales as continuous outcomes (an accepted meta-analytic technique for ordinal outcome data is not yet available). Where a lower value indicated a better outcome on a measurement instrument, we multiplied the reported values by −1, so that a higher value was indicative of a better outcome across all analyses. We extracted final-value scores for analysis. If RCTs reported change-from-baseline values and the baseline value was available, we calculated the final

value. If RCTs reported change values and the baseline value was not available, we used these data in meta-analyses but planned sensitivity analyses to investigate the effect of including the data.

Unit of analysis

Where RCTs had more than one eligible active intervention group within the same comparison (against a control, placebo, standard care or no treatment group), we divided the control group data between the multiple pairwise comparisons to ensure there was no double counting of participants within any one analysis.

Heterogeneity assessment

Statistical heterogeneity was calculated using the I^2 statistic; based on Cochrane guidance[222] we used the I^2 value to grade the level of heterogeneity:

- I^2 of 0 represents no heterogeneity.
- $0 < I^2 < 30$ may represent some heterogeneity.
- $30 \leq I^2 < 50$ may represent moderate heterogeneity.
- $50 \leq I^2 < 75$ may represent substantial heterogeneity.
- $75 \leq I^2$ may represent considerable heterogeneity.

We explored individual RCT characteristics to identify potential sources of heterogeneity.

Reporting bias assessment

We compared the availability of outcomes of interest with those reported in the included RCTs and noted where an outcome measurement was described but not reported or data were unavailable for analysis (see *Risk of bias*). We planned to examine publication bias using a funnel plot where ≥ 10 or more RCTs were identified and reported a single outcome.[225]

Assessment of the certainty of evidence

Confidence in the cumulative evidence for each meta-synthesis was independently judged by two reviewers (CH/ATB)[226,227] based on the following criteria.

Risk of bias: we judged the risk of bias for each RCT using the Cochrane ROB tool (see *Risk of bias*).[228]

Imprecision: we considered the number of studies/participants (up to two downgrades), whether the 95% CI excluded no effect (one downgrade) and presence of wide CIs (one downgrade).[229]

Inconsistency: we considered overlap of CIs (one downgrade) plus the results of tests of heterogeneity (one downgrade if $I^2 \geq 50\%$).[230]

Indirectness: we considered the demographic details of the included populations (one downgrade), the nature of the interventions (one downgrade) and the outcomes measured (one downgrade).[231]

Publication bias: where evidence of publication bias was identified, we planned to downgrade the evidence.[232]

Beginning with a default grade of high quality, one downgrade reduced the level of evidence to moderate quality, two downgrades meant reduced it to low quality and three or more downgrades reduced it to very low quality. We used the following definitions of evidence:

- High quality: very confident that the true effect lies close to that of the effect estimate.

- Moderate quality: moderately confident that the true effect is close to the effect estimate, but it is possible that there is a substantial difference.
- Low quality: limited confidence in the effect estimate; there may be a substantial difference between the effect estimate and the true effect.
- Very low quality: little confidence in the effect estimate; it is likely that there is a substantial difference between the effect estimate and the true effect.

Summary of findings

We summarised results and our judgements of quality of evidence for comparisons of interventions with no treatment or control, for outcomes of ADLs, extended activities of daily living (EADLs), QoL, psychological well-being and mental health, perception and adverse events. We created a summary of findings tables for each sense addressed by included RCTs.

Interpreting the findings

Our Clinical Expert and Lived Experience Groups informed our interpretation of the Cochrane Review findings [see *Stakeholder activities (what happened)* and *Report Supplementary Material 5*].

Cochrane Review submission and peer review

The updated and expanded Cochrane systematic review was submitted to the Cochrane Stroke Editorial Group in keeping with Cochrane Library publication protocols where it underwent peer review[233] by clinical experts, researchers and external stakeholders to ensure adherence to the appropriate Cochrane Review standards.[222]

Summary

This Cochrane Review revision and expansion aimed to synthesise the RCT evidence relating to the effectiveness of interventions for perceptual disorders after stroke. Subsequent to the scoping review, it used similar rigorous data search and selection process, but with narrower inclusion criteria, limiting to RCTs, adult participants and six outcomes. We explored the comparison of active interventions to (1) no treatment, (2) control and (3) other active interventions for perceptual disorders in six senses, conducting meta-analyses where possible. Risk of bias was assessed using Cochrane tools for included RCT, and the confidence in evidence judged using GRADE criteria for each comparison. We worked with stakeholders to discuss and agree the meaning of the results.

Chapter 7 Cochrane systematic review results

Introduction

In this chapter, the results of the Cochrane systematic review and synthesis of the RCT evidence relating to the benefits of interventions for perceptual disorders following stroke are presented.

Results of the systematic search

The original scoping review search (see *Chapter 5*) identified 27 trials (including four ongoing). New records were identified in our updated search; screening of titles and abstracts highlighted 77 full texts to be considered, in addition to 10 records from the 2011 Cochrane Review.[6] Of 113 full texts considered, we included 18 RCTs, with further studies ongoing (*n* = 11) or awaiting additional information prior to assessment (*n* = 11) (*Figure 9*).

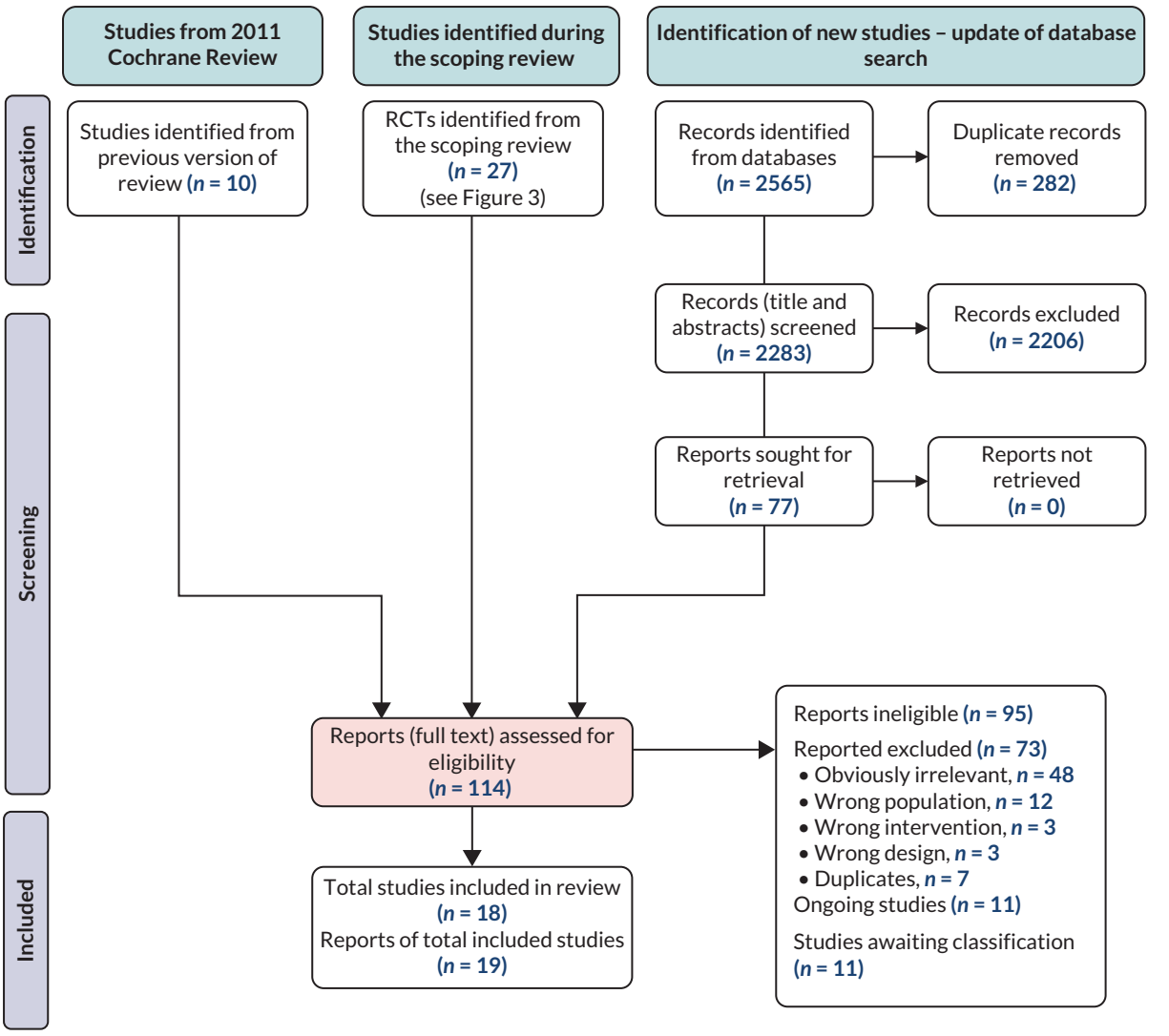

FIGURE 9 Preferred Reporting Items for Systematic Reviews and Meta-Analysis[128] for Cochrane Review literature identification.

Included studies and population

We included 18 RCTs (*n* = 541; see *Appendix 4* and *Report Supplementary Material 14*). Trials were conducted across seven countries in Asia, Australia, Europe and North America. Recruitment details were often absent or limited. Most RCTs (14/18, 77.8%) recruited from a single site, with three recruiting across two to six sites.[74,154,234] Trials took place in hospital or medical facilities; none were community based. One RCT used a crossover design.[235]

Included RCTs randomised between 11 and 80 (mean 29.9, SD 15.9) participants. Dropout details, including the participant numbers lost during intervention delivery or follow-up, are given in *Report Supplementary Material 15*. Of the 541 participants included, 535 (98.9%) were stroke survivors:[60,66,74,75,144,150,152,154,162,163,180,181,187,201,234–237] 17 RCTs recruited stroke survivors only, but Lincoln 1985[150] included 6/33 participants with head injury. Stroke duration onset varied, from approximately 19 days[187] to 4.3 years.[236] The mean participant age varied from 48.8[150] to 75.5 years,[234] and RCTs included participants with haemorrhagic and ischaemic stroke.

Included perceptual disorders and interventions

The review included 18 RCTs that evaluated interventions for tactile, somatosensation, visual and mixed perception disorders. No interventions for disorders of hearing, taste or smell perception were identified.

Thirty-two interventions were identified and represented two approaches (1) NIBS,[187] and (2) rehabilitation approaches; compensation (1 intervention),[60] restitution (25 interventions),[60,66,75,144,150,152,154,162,163,180,181,201,234–237] restitution combined with another rehabilitative approach (4 interventions),[74,163,181,235] unclear (1 intervention).[74]

The 18 included studies made 20 relevant comparisons:

- three intervention versus no treatment comparisons
- three interventions versus control (placebo/sham/control) comparisons
- Fourteen intervention 1 versus intervention 2 comparisons.

Somatosensory perception dysfunction

Population: One hundred and ninety-six participants in seven RCTs.[75,162,163,180,181,187,234] Somatosensory perception disorders included Pusher syndrome (five RCTs), diagnosed using the Burke Lateropulsion Scale[75,181] and Scale of Contraversive Pushing,[75,163,180] and less specific disorders of somatosensation, diagnosed via practical assessments, such as pinprick and tight touch tests.[187,234] For analysis, we split these into 'Pusher syndrome' or 'not Pusher syndrome'. Further population information is given in *Report Supplementary Material 16*.

Interventions:

- Rehabilitation (restitution) (10 interventions) – game-based vertical posture training (*n* = 2),[75,162] standard posture training (*n* = 2),[75,162] conventional physiotherapy (for Pusher syndrome) (*n* = 2),[163,234] physiotherapy + sensorimotor training,[234] physiotherapy + motor training,[234] computerised interactive visual feedback training (WiiFit),[180] mirror feedback training.[180]
- Rehabilitation (restitution and substitution) (*n* = 2 studies) – robot-assisted gait training.[163,181]
- NIBS (one intervention) – tDCS.[187]

Materials and procedures: One NIBS intervention used relevant equipment to deliver tDCS stimulation to the appropriate hemisphere and region.[187] All other interventions used rehabilitative approaches:

for Pusher syndrome therapy these could be grouped into either (1) game-based postural training, with supporting equipment, or (2) conventional physiotherapy for Pusher syndrome; for non-pusher disorders one RCT explored sensory-motor training focusing on sense discrimination, and table-top 'motor therapy'.

Game-based postural training used one of three named interventions: WiiFit (computer-based exercises and balance board),[180] Lokomat (computer-based exercises, supportive harness and treadmill)[163,181] and Spine Balance 3D (computer-based exercises and whole-body tilt apparatus).[75,162] Each was used to provide physical therapy, with participants asked to achieve a set body position or movement in response to the computerised exercises, and in relation to any positional change caused by the associated equipment.

Conventional physiotherapy for Pusher syndrome often involved postural training and weight shifting, using visual cues in the room to regulate posture, alongside verbal feedback from the therapist. Materials used were often unclear but included a chair for seated exercises and a mirror for feedback.[75,162,163,180,181]

Sensory-motor training used the SENSe approach with three sensory discrimination tasks: texture discrimination, limb position sense and object recognition.[234] Materials in these tasks included different textures (fabric, wallpaper, plastic and sandpaper), different objects of varying shape, size and materials. A range of exercises were used, such as smoothing out fabric while appreciating the texture, moving the limb to a specific position and arranging bottles in order of weight. *Motor therapy* used tabletop games such as chess (with clear cognitive and attentional demand), with a set programme of upper limb exercises used to improve gross movement and dexterity.[234]

Delivery: All interventions were delivered one to one, in a hospital setting. A physiotherapist delivered 5 of 13 interventions (which for 1 RCT specified that they had 'more than 5 years' experience')[162,180,181] while the remaining providers were not reported, or unclear.

Schedule and duration: There was similarity in the schedule and duration of the rehabilitation interventions. Sessions typically lasted 30–60 minutes per day, 3–5 times per week, for a duration of 2–4 weeks in total. In contrast, NIBS was delivered for 20 minutes per day for 10 days.[187]

Tailoring and modification: Tailoring of interventions varied; seven interventions did not report tailoring.[75,162,163,180,187,234] Others reported that exercises were tailored to the participant's ability before training began[75,162,181,234] or that the difficulty level was altered relative to performance; for example the 'the speed and range of trunk movement' was increased or exercises were 'changing from sitting to standing.'[162] Detailed intervention descriptions are given in *Report Supplementary Material 14*. Intervention modifications were not reported by any RCT.

Tactile perception dysfunction

Population: Seventy participants with tactile perceptual dysfunction, in three RCTs.[201,235,236] Diagnostic tools included the revised Nottingham Sensory Assessment (rNSA)[235] and Semmes Weinstein monofilament[201,236] (see *Report Supplementary Material 16*).

Interventions:

- Four rehabilitation (restitution) interventions – pressure sense perception training on stable surface,[201] pressure sense perception training on unstable surface,[201] hand exercises (without glove)[235] and a vibrating glove 'VTS Glove.'[236]
- One rehabilitation (restitution and substitution) intervention – robot glove-based hand exercises.[235]

Materials and procedures: Interventions were of two main types – pressure sense training involving exercises on a stable or unstable surface,[201] and hand exercises, either with or without a glove to assist.[235,236] With *pressure sense training*, participants stood on either a stable foam block, or on an

unstable balance pad. They were asked to shift weight to their affected side, and pressure in the heel was measured to ensure a desired level was reached.[201] *Hand exercises* included a range of passive range of motion tasks, and task-based activities and games. The addition of a robotic glove was used to detect movement and provide a simultaneous display of performance on a computer screen, as well as providing sensory stimulation.[235] A different, vibrating, glove was used to provide stimulation to skin on the palm and fingers; it did not require any exercises.[236]

Delivery: Interventions were delivered by physiotherapists (two interventions[201]), OTs (two interventions[235]) in one-to-one sessions in a hospital setting (four interventions[201,235]), with the vibrating glove used by participants themselves at home (one intervention[236]).

Schedule and duration: Varied from 30-minute sessions, 3 days per week[201] to 3-hour sessions, 7 days per week.[236] Total duration ranged from 4 to 8 weeks.

Tailoring and modification: Tailoring to participants' ability was not reported for two interventions.[235,236] Pressure sense training was tailored to participants' heel pressure, and allowed progression to a more difficult stage when a suitable pressure level was achieved,[201] and robot-assisted hand exercise settings were adjusted to participants' ability.[235] Detailed intervention descriptions are given in *Report Supplementary Material 14*. No modifications of the interventions during the RCT were reported.

Visual perception dysfunction

Population: Two hundred and twenty-five participants, in seven RCTs.[60,66,144,150,152,154,237] Visual perception disorders were diagnosed using specialised tests such as the MVPT or Rivermead Perceptual Assessment Battery,[144,237] cognitive tests that include visual perception subsections (Modified Mental State Examination),[66,152] and a complex figure-drawing test to test for visual memory deficit.[154]

Interventions:

- Eleven rehabilitation (restitution) interventions – image drawing – global processing training,[154] image drawing – rote repetition training,[154] neurofeedback (NFB) training,[66] WiiFit virtual reality training (WVRT),[144] general balance training,[144] transfer of training perceptual treatment,[60] computerised visual perception rehabilitation with motion tracking,[237] computer-based cognitive rehabilitation program,[237] OT-led perceptual training,[150] computer-based cognitive rehabilitation training,[152] conventional cognitive rehabilitation.[152]
- One rehabilitation (compensation) intervention – functional perceptual treatment.[60]

Materials and procedures: All interventions used a rehabilitation approach and grouped into five main types: paper-based tasks, OT-led task-based training, physical interventions, cognitive and perceptual exercises and neurofeedback training.

Three interventions used *paper-based tasks*: in two, participants traced then reproduced a complex figure (Rey–Osterrieth Complex Figure) either as a whole figure or broken down into its component parts[154]; the third used 'conventional cognitive rehabilitation', the exact nature of which was not clearly stated.[152] Three interventions used an *OT approach*, training visual perceptual skills using functional and task-based training.[60,150] Although not well described, this training included simple perceptual activities such as stick length sorting, colour matching and parquetry mosaic tasks. One RCT explored *physical interventions* for visual perceptual disorders alongside balance disturbance.[144] WiiFit with balance board training used a range of activities to stimulate interest and motivation, such as simulated tightrope walking and slalom, and that encouraged multidirectional weight shifting. Balance training used a balance board, with the participant asked to shift weight, using a mirror for feedback. One approach used *computerised exercises* – these frequently were called 'cognitive' in nature, but had a clear focus on improving visual perceptual skills, including object recognition, object constancy, figure-ground organisation, visual discrimination and visual organisation.[152,237]

Delivery: Delivery was poorly reported for visual perceptual disorder interventions. Where reported, a physiotherapist (one intervention[144]) and OT (three interventions[235,237]) delivered interventions on a one-to-one basis, in hospital settings.

Schedule and duration: Two interventions (involving paper-based repetition training) were delivered in a single 90-minute session.[154] For the other interventions, sessions typically lasted 30 minutes, 3–5 times per week, for 4–6 weeks.

Tailoring and modification: Tailoring was either not reported or was unclear for nine interventions; in three others, the intervention exercises and difficulty were based on the participant's perceptual ability.[150,152] No intervention modifications were reported.

One RCT (50 participants) explored a mixed perceptual disorder, addressing tactile-somatosensory disorder. Mixed-sensory categories were not included in our analysis plan and were thus excluded.

Outcome measures

Our primary outcome, ADLs was measured by seven RCTs, using the Modified Barthel,[60,235,237] Korean Modified Barthel[75,162,181,187] and Edmans ADLs Index.[60]

The frequency of reporting secondary outcomes varied; perception (11 RCTs), adverse events (6 RCTs), mobility and navigation (4 RCTs) and EADLs (1 RCT). No RCTs reported measures of social activity and participation, QoL, or psychological well-being and mental health outcomes (see *Report Supplementary Material 17*).

Six RCTs reported adverse events. It was unclear whether the data reported described the number of participants experiencing an adverse event or the number of adverse events experienced across the RCT population. We chose to present this narratively.

All five RCTs evaluating interventions for Pusher syndrome used severity outcome measures (Burke Lateropulsion Scale, Scale for Contraversive Pushing). We extracted, analysed and presented this data, as it provided treatment effectiveness information relevant to clinical practice.

Excluded studies

We excluded 73 studies with reasons provided for 18 where decisions were more difficult (see *Report Supplementary Material 18*). The main reason for exclusion was the absence of a perceptual disorder diagnosis.

Ongoing studies

We identified 11 ongoing RCTs of interventions, and in most cases these could be related to disorders of perception in specific senses: smell (1 RCT), somatosensation (7 RCTs) and visual perception (2 RCTs)[238–246] (see *Report Supplementary Material 19*).

Studies awaiting classification

Eleven RCTs identified are awaiting classification[159,172,202,203,247–252] (see *Report Supplementary Material 20*). As we could not determine if they met inclusion criteria these were not included; their status will be reconsidered at the point that any updates of this Cochrane Review are conducted.

Risk of bias in included studies

We evaluated included RCTs risk of bias (see *Risk of bias*) and provided an overview of these risks in *Figure 10* (individual study risk of bias data is in *Report Supplementary Material 14*, risk of bias summary is given in *Report Supplementary Material 21*).

Randomisation and concealment of allocation

All included RCTs described random sequence generation, but the method used was unclear for five RCTs.[66,75,144,150,236] The concealment of allocation was clearly stated by six RCTs,[60,74,154,162,163,234] including sealed, opaque envelopes or a sealed box.

Blinding

In complex rehabilitation RCTs, adequate blinding of clinicians delivering and participants receiving an intervention is a significant challenge; no RCTs were assessed as having a low risk of bias. Blinding of outcome assessors was reported by 13 RCTs but was unclear for 5 RCTs.[66,75,152,181,201] Six RCTs were judged as having a high risk of bias.[60,74,144,154,234,237]

Incomplete outcome data

Three RCTs were judged as unclear[66,150,154] in their reporting of attrition bias with the remaining RCTs either including all participants in their analyses or accounting for all participants (with reasons given for dropout) and an intention-to-treat analysis conducted. One RCT[234] had a high risk of bias as three participants were excluded from primary and follow-up analysis.

Selective reporting

For 16 RCTs, outcome measures were well reported. Only one RCT provided partial data for three outcomes[234] and a further RCT[74] failed to provide data for secondary outcomes.

Other potential sources of bias

Two RCTs had a high risk of bias. In one,[163] several participants had severe cognitive deficits and the authors stated these deficits might have influenced the participants' response to the intervention, although there were no data to support this intervention response. In a second,[234] the mean age of the experimental group was significantly higher than the control group, and with more right hemispheric lesions.

Comparability of groups at baseline was adequate for 11 RCTs,[60,74,144,154,162,180,181,187,201,235,237] while 5 RCTs were judged unclear. This was due to a lack of reporting of the baseline characteristics of participants[66,152,236] or due to difficulties 'securing homogeneity' of participants, the nature of which was not fully explained.[75] For one,[150] there was a change to eligibility criteria part-way through the RCTs to address slow recruitment: the RCT included those left hemisphere strokes, subarachnoid haemorrhage and head injury. It is unclear what interim analyses were undertaken and what the decision-making process was for continuation, adaptation and eventual stopping of the RCT.

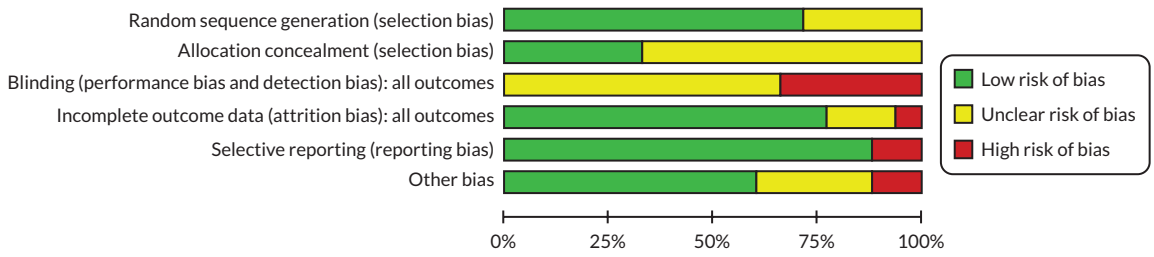

FIGURE 10 Risk of bias graph: judgements on each methodological quality item presented as percentages across all included studies. Note: this figure is based on one published in CDSR.[204]
Reproduced with permission from Hazelton *et al.*[204] This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The text below includes minor additions and formatting changes to the original text.

Effects of interventions

Hearing

There were no RCTs of interventions for hearing perceptual disorders.

Smell

There were no RCTs addressing smell perceptual disorders.

Somatosensation

We identified seven relevant RCTs: five recruited people with Pusher syndrome[75,162,163,180,181] and two included participants without Pusher syndrome[187,234] (*Table 7*).

Intervention versus no treatment or control

Pusher syndrome

No RCTs.

Not Pusher syndrome

One RCT,[187] comparing tDCS to sham treatment.

Activities of daily living

- One RCT (24 participants);[187] *Figure 11*.
- ADLs measured using the Korean Modified Barthel Index.
- Analysis showed **no difference between active intervention and control** (MD 10.08, 95% CI −2.47 to 22.63, $p = 0.12$); the evidence was of very low certainty.

Mobility

- One RCT (24 participants);[187] *Figure 12*.
- Mobility assessed using the Functional Ambulation Category.
- Analysis showed **no difference between active intervention and control** (MD 0.50, 95% CI −0.38 to 1.38, $p = 0.27$); the evidence was judged to be of very low certainty.

Perception

- One RCT (24 participants).[187]
- Measured somatosensory perception (modified Nottingham Sensory Assessment).
- Summary data were unreported (subscales only) and could not be included in analysis.

Adverse events

- One RCT[187] (24 participants).
- Stated that 'all the participants completed the stimulation sessions successfully without complaining about any discomfort during the procedure'.

Intervention 1 versus intervention 2

Pusher syndrome

Five RCTs addressed this comparison.[75,162,163,180,181] All RCTs compared an intervention training posture or/and movement using equipment such as balance boards, treadmills or harnesses alongside computerised to conventional physiotherapy for Pusher syndrome. Interventions in both groups were considered similar and the data were combined in meta-analyses.

TABLE 7 Summary of findings for somatosensory perception disorders – active intervention compared with no treatment or control

Patient or population: Stroke survivors with somatosensory perception disorders
Settings: Any
Intervention: Rehabilitation for Pushers or Rehabilitation for non-Pushers
Comparison: No treatment or control

Outcome (at end of intervention period)	Comparison	Relative effect (95% CI)	*n* (RCTs)	GRADE	Comments
ADLs – rehabilitation for non-Pushers	Active intervention vs. no treatment	-	no studies	-	
	Active intervention vs. control	MD 10.08 (−2.47 to 22.63)	24(1) (Koo 2018)[187]	Very low[a,b,c]	No difference between intervention and control
EADLs	Active intervention vs. no t)reatment or vs. control	-	No studies	-	
QoL – mobility and navigation – rehabilitation for non-Pushers	Active intervention vs. no treatment	-	No studies	-	
	Active intervention vs. control	MD 0.50 (−0.38 to 1.38)	24 (1) study (Koo 2018)[187]	Very low[a,b]	No difference between intervention and control
Psychological well-being and mental health	Active intervention vs. no treatment or vs. control	-	No studies	-	
Perception	Active intervention vs. no treatment	-	No studies	-	
	Active intervention vs. control	Insufficient detail to allow analysis	24 (1) (Koo 2018)[187])	-	
Adverse events	Active intervention vs. no treatment	-	No studies	-	
	Active intervention vs. control	Insufficient detail to allow analysis	24 (1) (Koo 2018)[187]		Authors stated that 'all the participants completed the stimulation sessions successfully without complaining about any discomfort during the procedure'

GRADE
a At least one RoB category is high or uncertain.
b Very small number of participants/studies.
c Very wide CI(s).

Note
Table is based on one published in CDSR.[204]

Activities of daily living

- Three RCTs (80 participants);[75,162,181] *Figure 13*.
- ADLs assessed using the Korean Modified Barthel index.
- **Intervention 1 (computerised balance and movement training) was more beneficial than Intervention 2 ('standard' Pusher syndrome physiotherapy)** [MD 10.19 (4.94 to 15.44), $p = 0.0001$]; there was no heterogeneity ($I^2 = 0\%$) and evidence was of very low certainty.

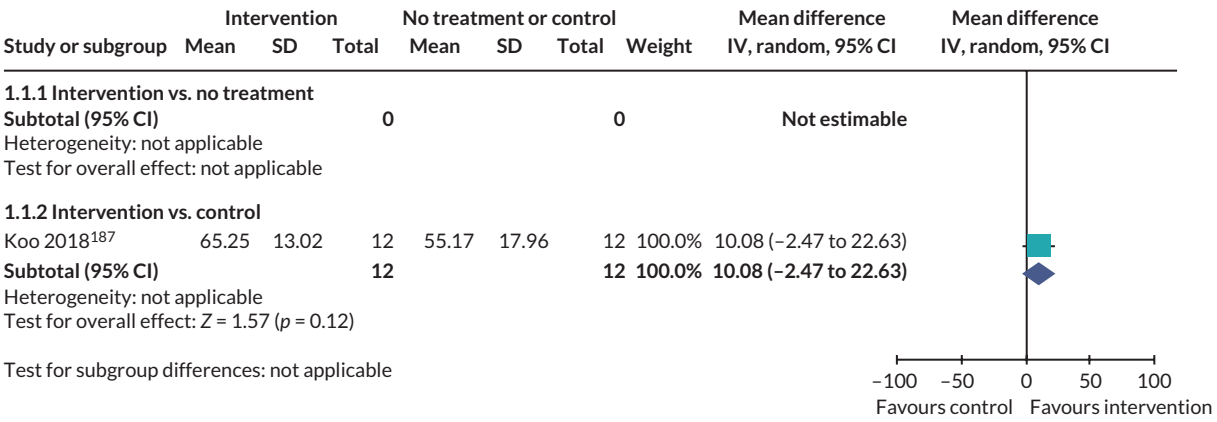

FIGURE 11 Comparison of intervention vs. no treatment or control for somatosensory disorders. Outcome – ADLs. Note: All forest plots in this chapter are taken from the review published in CDSR.[204]
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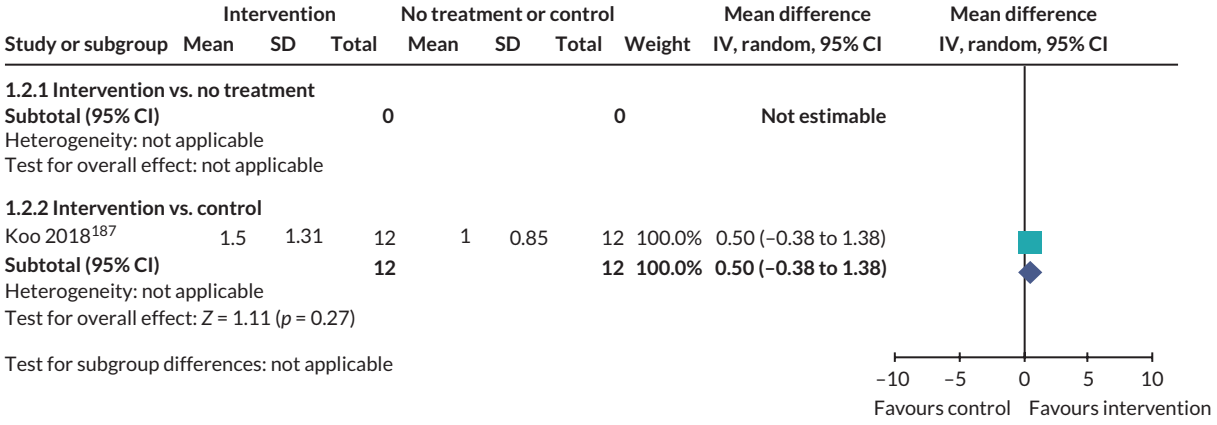


FIGURE 12 Comparison of intervention vs. no treatment or control for somatosensory disorders. Outcome – mobility and navigation.

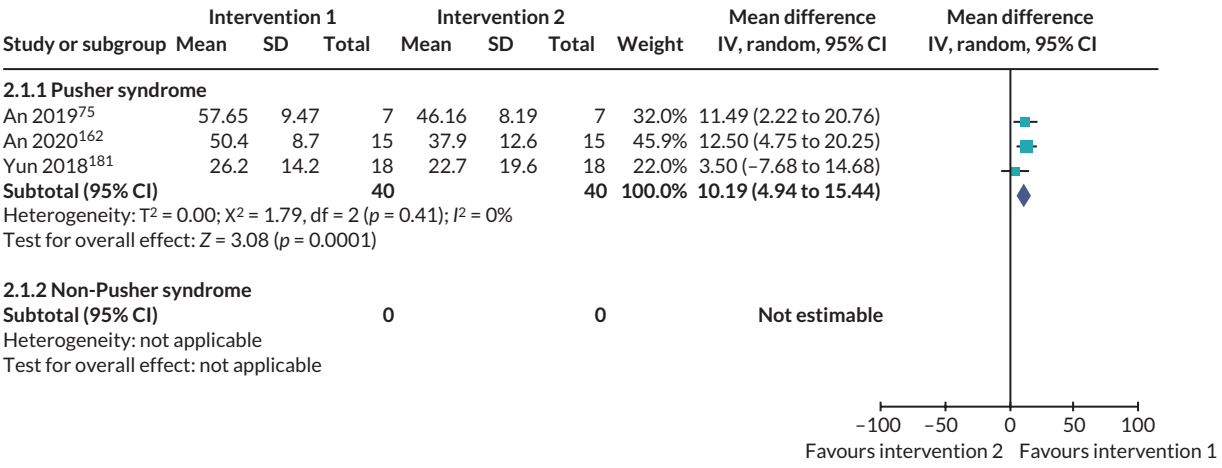


FIGURE 13 Comparison of active intervention 1 vs. active intervention 2 for somatosensory perception disorder. Outcome – ADLs.

Mobility

- One RCT (30 participants);[163] *Figure 14*.
- Mobility assessed using the Performance Oriented Mobility Assessment – Balance (POMA-B) outcome measure.
- Analysis showed **no evidence of a difference between Interventions 1 and 2** [MD 1.00 (−1.51 to 3.51)]. Evidence was judged to be of very low certainty.

Perception

- One RCT (30 participants);[163] *Figure 15*.
- Assessed perception via subjective visual vertical test.
- There was **no evidence of a difference between intervention 1 and 2** [standardized mean difference – SMD 0.52 (−0.21 to 1.25)]. Evidence was judged to be of very low certainty.

Adverse events

Three studies reported on adverse events;[75,162,181] in each case none had occurred.

Pusher syndrome outcomes

- Four RCTs (86 participants); *Figure 16*.
- Pusher syndrome severity assessed using the Burke Lateropulsion Scale[75,162] or the Scale of Contraversive Pushing.[163,180]
- Analysis showed a tendency for **intervention 1 (computerised balance and movement training) to be more beneficial than intervention 2 (standard Pusher syndrome physiotherapy)** (SMD 1.03, 95% CI 0.33 to 1.73), $p = 0.004$). Results may suggest substantial heterogeneity ($I^2 = 50\%$), and the evidence was judged to be of very low certainty.

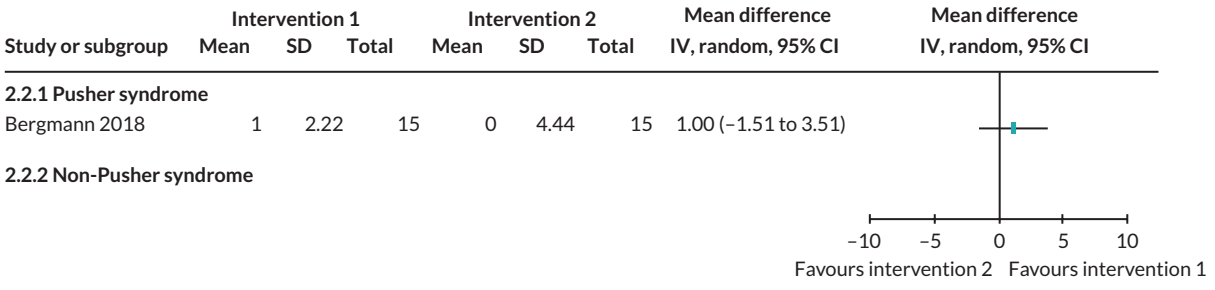


FIGURE 14 Comparison of active intervention 1 vs. active intervention 2 for somatosensory perception disorder. Outcome – mobility and navigation.

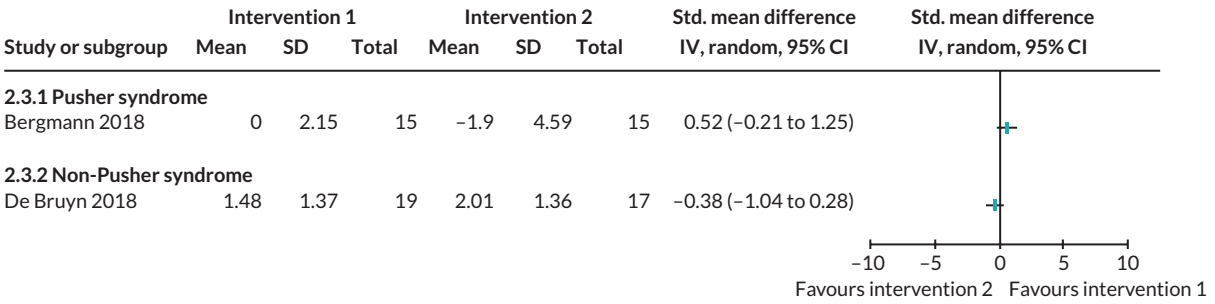


FIGURE 15 Comparison of active intervention 1 vs. active intervention 2 for somatosensory perception disorder. Outcome – perception.

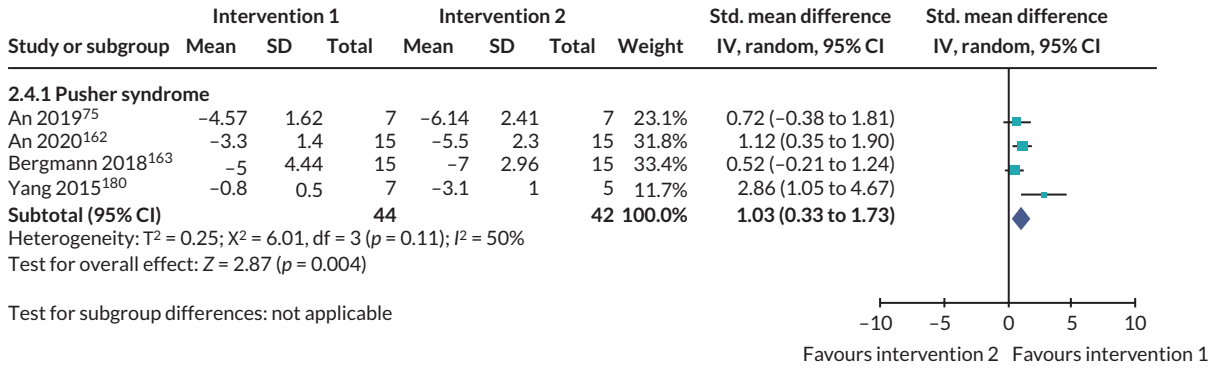


FIGURE 16 Comparison of active intervention 1 vs. active intervention 2 for somatosensory perception disorder. Outcome – Pusher syndrome outcomes.

Not Pusher syndrome

One RCT[234] addressed this comparison, comparing the SENSe intervention, consisting of sensorimotor therapy and sensory discrimination tasks, with cognitive table-top games and motor exercises.

Perception

- One RCT (36 participants);[234] *Figure 15*.
- Perception assessed using the Nottingham Sensory Assessment.
- Analysis showed **no evidence of a difference between intervention 1 and intervention 2** (SMD −0.38, 95% CI −1.04 to 0.28); the evidence was very low certainty.

Tactile

We identified three relevant RCTs.[201,235,236] Data contributed to analysis by Kim (2015)[201] and Lee (2021)[235] (*Table 8*).

Intervention versus no treatment or control

One RCT compared two active interventions with no treatment.[201]

Quality of life – navigation and mobility

- One RCT with two relevant comparisons (30 participants);[201] *Figure 17*.
- Mobility and navigation were measured using the timed-up-and-go measure.
- Analysis showed **no difference between active intervention and no treatment** (MD 6.50, 95% CI −4.81 to 17.81, $p = 0.26$). Results may suggest substantial heterogeneity ($I^2 = 50\%$). Due to a number of methodological concerns, it was judged there was insufficient evidence to support a conclusion based on these data.

Perception

- One RCT with two relevant comparisons (30 participants);[201] *Figure 18*.
- Perception was assessed using a dynamometer-based measure of proprioception.
- Analysis showed that **a tendency for active intervention was more beneficial than no treatment** (MD 4.64, 95% CI 3.06 to 6.22, $p \leq 0.00001$). Results showed no heterogeneity ($I^2 = 0\%$), and the evidence was judged to be of very low certainty.

Active intervention 1 versus active intervention 2

Two RCTs addressed this comparison: one[235] compared robot gloved-based hand exercises to hand exercises alone, and another[201] compared pressure sense perception training on a stable surface to an

TABLE 8 Summary of findings for tactile perception disorders – active intervention vs. no treatment or control

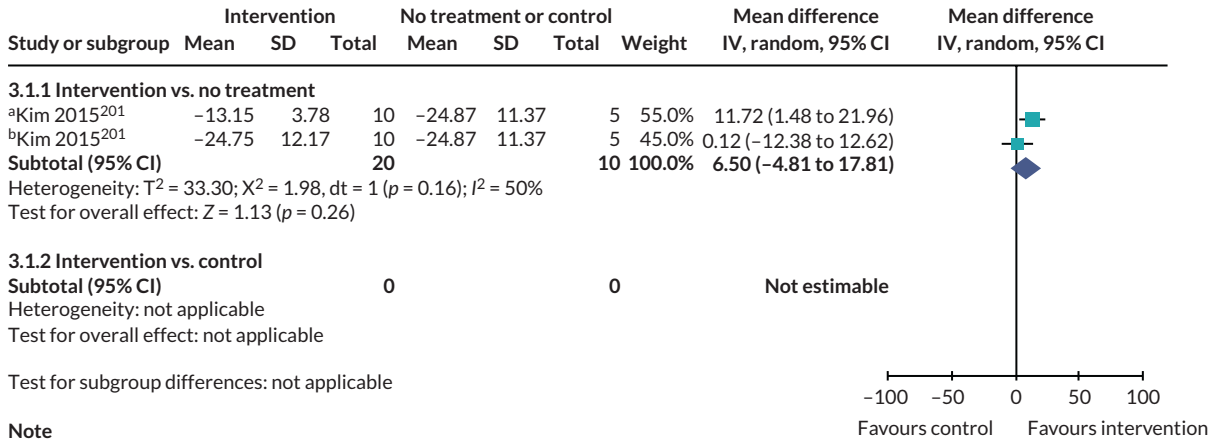
Rehabilitation interventions compared to no treatment or control for tactile perception disorders

Patient or population: Stroke survivors with tactile perception disorders
Settings: Any
Intervention: Rehabilitation
Comparison: No treatment or control

Outcome (at end of intervention period)	**Comparison**	**Relative effect (95% CI)**	*n* (RCTs)	GRADE	comments
ADLs	Active intervention vs. no treatment or vs. control	-	No studies	-	
EADLs	Active intervention vs. no treatment or vs. control	-	No studies	-	
QoL – mobility and navigation	Active intervention vs. no treatment	MD 6.50 (−4.81 to 17.81)	30 (2) Kim 2015 (stable),[201] Kim 2015 (unstable)[201]	Insufficient evidence[a,b,c,d,e,f]	A number of methodological concerns led to the judgement that there was insufficient evidence to support a conclusion based on these data
	Active intervention vs. control	-	No studies	-	
Psychological well-being and mental health	Active intervention vs. no treatment or vs. control	-	No studies	-	
Perception	Active intervention vs. no treatment	MD 4.64 (3.06 to 6.22)	30 (2) – Kim 2015 (stable),[201] Kim 2015 (unstable)[201]	Very low[a,b,f]	Favours intervention
	Active intervention vs. control	-	No studies	-	

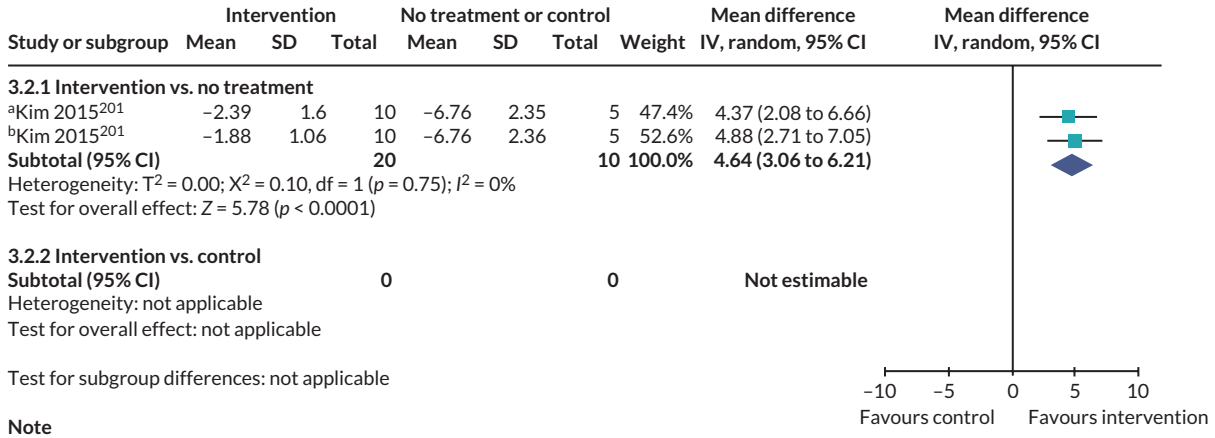
GRADE reasons for downgrade:
a At least one RoB category is high or uncertain.
b Very small number of participants/studies (2 downgrades).
c Poor overlap of CIs.
d Heterogeneity, as indicated by $I^2 \geq 50\%$.
e Uncertainty regarding the unit of data presented for this outcome (states time in methods section and speed in results table; assumed to be time for direction of analysis).
f Baseline differences between groups for this outcome.

Note
Table is based on one published in CDSR.[204]



Note
[a] This comparison relates to training on an unstable surface vs. no treatment.
[b] This comparison relates to training on a stable surface vs. no treatment.

FIGURE 17 Intervention vs. no treatment or control for tactile perception disorder. Outcome – mobility and navigation.



Note
[a] This comparison relates to training on an unstable surface vs. no treatment.
[b] This comparison relates to training on a stable surface vs. no treatment.

FIGURE 18 Intervention vs. no treatment or control for tactile perception disorder. Outcome – perception.

unstable one (balance board). As the interventions were quite different, data were not combined in meta-analysis.

Activities of daily living

- One RCT (24 participants);[235] *Figure 19*.
- ADLs were assessed using the Modified Barthel Index.
- This RCT demonstrated no difference between the interventions (MD −0.41, 95% CI −12.31 to 11.49). The evidence was considered to be of very low certainty.

Quality of life – navigation and mobility

- One RCT (20 participants);[201] *Figure 20*.
- Mobility and navigation were assessed using the timed-up-and-go measure.
- This RCT provided evidence that intervention 2 (training on the unstable balance board) was more beneficial than intervention 1 (training on the stable balance board) (MD −11.60, 95% CI −19.50 to −3.70). The evidence was judged to be of very low certainty.

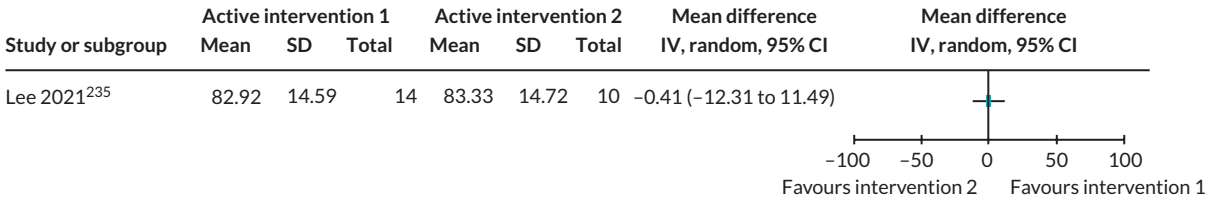


FIGURE 19 Active intervention 1 vs. active intervention for tactile perception disorder. Outcome – ADLs.

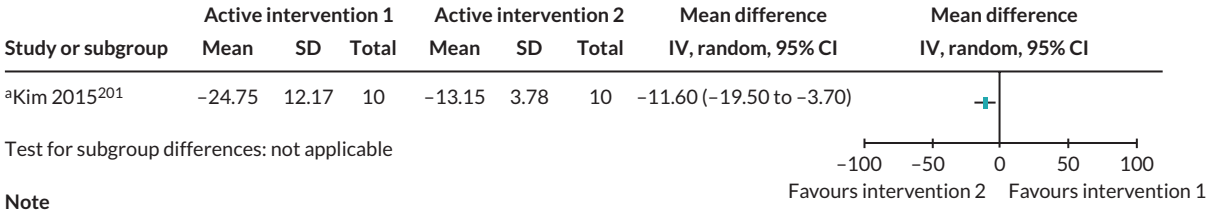


FIGURE 20 Active intervention 1 vs. active intervention for tactile perception disorder. Outcome – mobility and navigation.

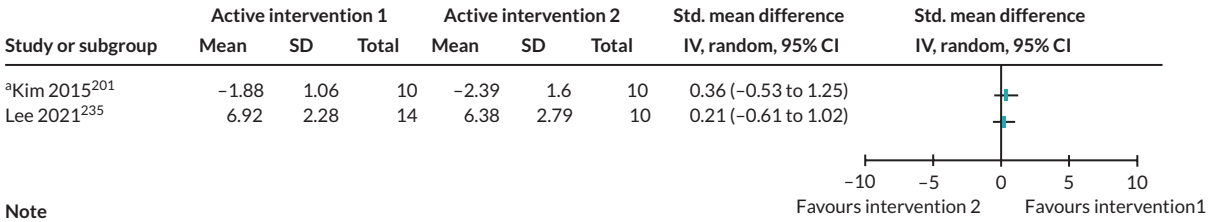


FIGURE 21 Active intervention 1 vs. active intervention for tactile perception disorder. Outcome – perception.

Perception

- Two RCTs (44 participants);[201] *Figure 21*.
- One assessed proprioception using a dynamometer and the other used the kinaesthetic subtest of the rNSA.
- Analysis did not combine data for these two RCTs: individually neither RCT provided evidence of a difference between interventions 1 and 2.

Adverse events

One RCT[235] collected data on adverse events, reporting 'no safety concerns or adverse events'.

Taste

No RCTs of interventions addressing taste perception disorder were identified.

Vision

There were seven relevant RCTs[60,66,144,150,152,154,236] (*Table 9*).

Intervention versus no treatment or control

One RCT compared intervention (neurofeedback training) with no treatment,[66] and one RCT compared intervention (perceptual training) with control (conventional (not perceptual) therapy).[150]

TABLE 9 Summary of findings for vision perception disorders – active intervention vs. no treatment or control

Rehabilitation interventions compared to no treatment or control for vision perception disorders					
Patient or population: Stroke survivors with vision perception disorders **Settings:** Any **Intervention:** Rehabilitation **Comparison:** No treatment or control					
Outcome (at end of intervention period)	**Comparison**	**Relative effect (95% CI)**	*n* (RCT)	GRADE	Comments
ADLs	Active intervention vs. no treatment or vs. control	-	No studies	-	
EADLs (Analysis 5.1)	Active intervention vs. no treatment	-	No studies	-	
	Active intervention vs. control	MD 0.94 (−1.60 to 3.48)	33 (1) Lincoln 1985[150]	Very low[a,b]	No difference between groups
QoL – social and participation/QoL/ mobility and navigation		-	No studies	-	
Psychological well-being and mental health		-	No studies	-	
Perception	Active intervention vs. no treatment	MD −1.75 (−5.39 to 1.89)	27 (1) Cho 2015[66]	Very low[a,b,c]	No difference between groups
	Active intervention vs. control	-	No studies	-	
Adverse events	Active intervention vs. no treatment or vs. control	-	No studies reported adverse events	-	

GRADE reasons for downgrade:
a At least one RoB category is high or uncertain.
b Very small number of participants/studies (2 downgrades).
c Baseline differences between groups.

Note
Table is based on one published in CDSR.[204]

EADLs

- One RCT (33 participants);[150] *Figure 22*.
- ADLs were assessed using the Rivermead ADLs scale.
- Analysis showed there was no evidence of a difference between active intervention and control (MD 0.94, 95% CI −1.60 to 3.48, $p = 0.47$). The evidence was judged to be of very low certainty.

Perception

- One RCT (27 participants);[66] *Figure 23*.
- Perceptual outcomes assessed using the MVPT. Another RCT[150] measured perception using the Rivermead Perceptual Assessment Battery: as only subscale scores for the Rivermead Perceptual Assessment Battery were reported, the data were not included in the analysis.
- Analysis showed no difference between active intervention and no treatment (MD −1.75, 95% CI −5.39 to 1.89, $p = 0.35$). The evidence was judged to be of very low certainty.

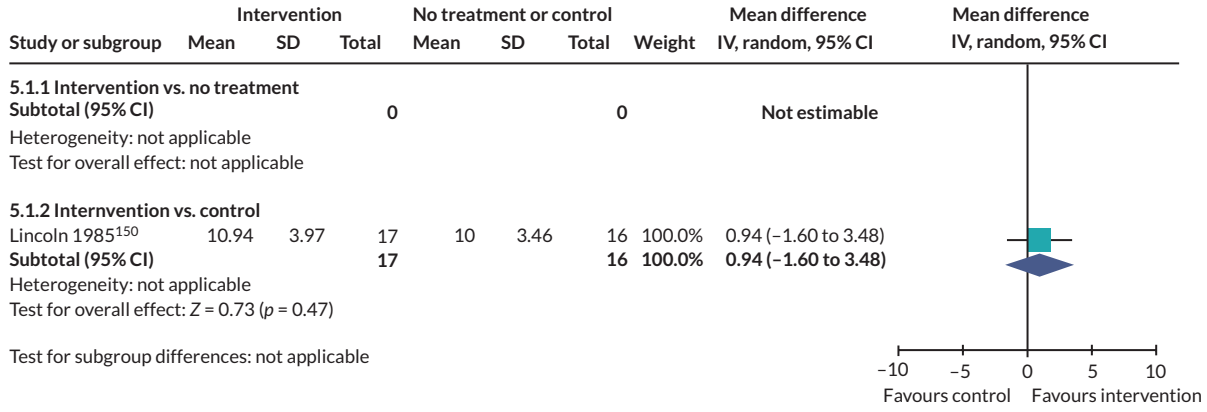


FIGURE 22 Intervention vs. no treatment or control for visual perception impairment. Outcome – EADLs.

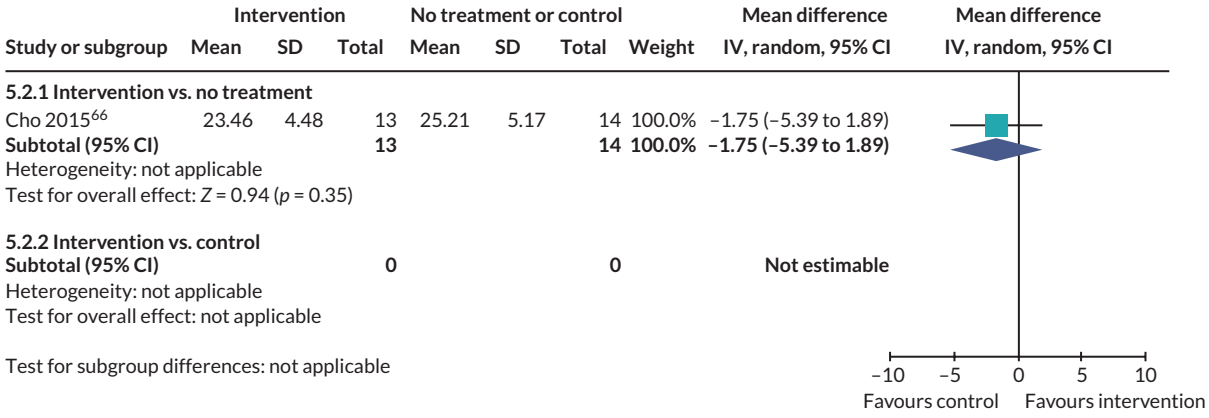


FIGURE 23 Intervention vs. no treatment or control for visual perception impairment. Outcome – perception.

Active intervention 1 versus active intervention 2

Five RCTs addressed this comparison.[60,144,152,154,237] The interventions were dissimilar, including OT-led training in practical tasks, paper-based repetition exercises and computer-based games; statistical pooling of data was inappropriate.

Activities of daily living

- Two RCTs (96 participants);[60,237] *Figure 24*.
- ADLs were assessed using the Modified Barthel Index.
- Data were not combined due to differences in the interventions. The evidence from each included RCT was judged to be of very low certainty.

Quality of life – mobility and navigation

- One RCT (28 participants);[144] *Figure 25*.
- 10-m walking test used to assess mobility. This compared with the WVRT versus general balance training for visual perceptual disorders.
- This RCT showed no evidence of a difference between the two interventions (MD −0.12, 95% CI −13.62 to 13.38); evidence was judged to be of very low certainty.

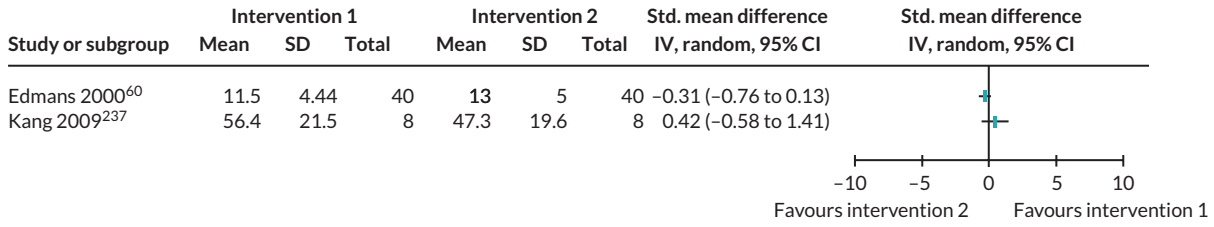


FIGURE 24 Active intervention 1 vs. active intervention for visual perception impairment. Outcome – ADLs.

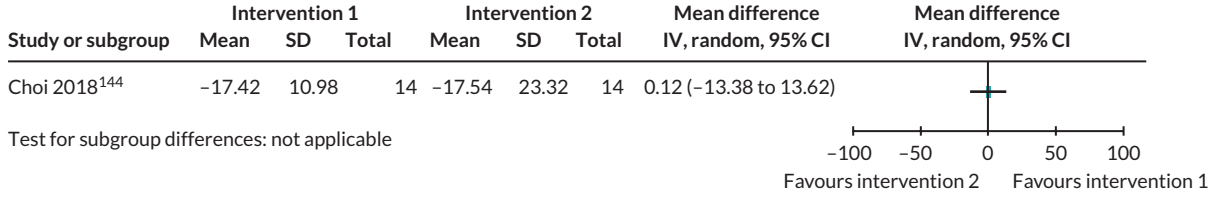


FIGURE 25 Active intervention 1 vs. active intervention for visual perception impairment. Outcome – mobility and navigation.

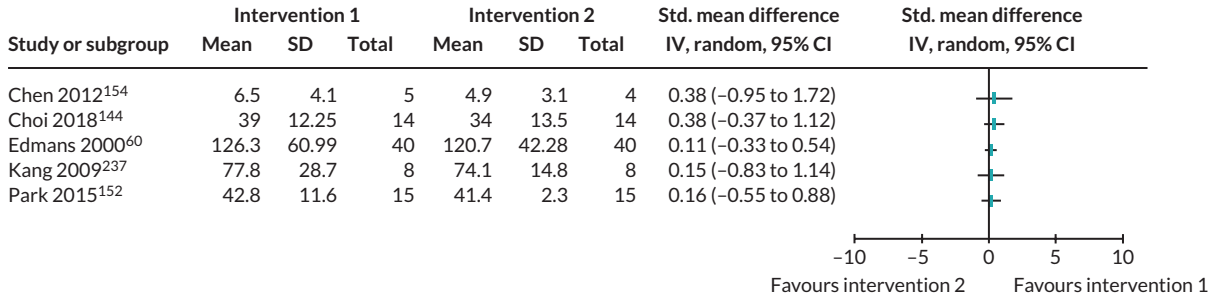


FIGURE 26 Active intervention 1 vs. active intervention for visual perception impairment. Outcome – perception.

Perception

- Five RCTs (163 participants);[60,144,152,154,237] *Figure 26*.
- A range of perception outcomes were used: Modified Taylor Complex Figure,[154] MVPT,[60,144,152,237] and Rivermead Perceptual Assessment Battery.[60]
- Data were not pooled due to differences in the interventions but were displayed as standardised MDs. The evidence from each included RCT was judged to be of very low certainty.

Interpretation of Cochrane Review results

Stakeholders reflected on the implications of the Cochrane systematic review findings in relation to the senses [see *Stakeholder activities (what happened)*, Activity 4]. They expressed disappointment at the lack of RCTs and suggested that the interventions evaluated in the included RCTs did not reflect 'real-world' experience. They encouraged collaboration between clinicians and researchers, highlighting its importance in identifying and evaluating clinical practice for people with perception problems. Details of the key issues are provided in *Report Supplementary Material 5*.

Summary

This chapter presents the results of the Cochrane systematic review update, exploring the effectiveness of interventions for perceptual disorders in stroke. We identified 18 eligible RCTs, involving 539 participants. Trials addressed tactile (three RCTs, *n* = 70), somatosensory (seven RCTs, *n* = 194) and visual perception disorders (seven RCTs, *n* = 225), with one (*n* = 50) addressing a mixed population. There were no RCTs addressing hearing, smell or taste perceptual dysfunction.

There was insufficient evidence to determine the effectiveness of any one intervention for any sensory modality, nor the effect of one intervention relative to another. The quality of evidence was either low or very low across comparisons. Analysis was limited by the low number of included RCTs and participants, the small number comparing active treatment to no treatment or control, and the limited use of ADLs as an outcome measurement, our primary outcome measure. Our confidence in this evidence is considered in *Chapter 10*.

Chapter 8 Integration and priority setting

Introduction

In this chapter, we describe the clinical and research implications arising from integration of the scoping and Cochrane systematic review findings and input from our Lived Experience and Clinical Expert Groups. Together with the stakeholder group, we considered the findings of the scoping review (see *Chapter 5*) and Cochrane systematic review (see *Chapter 7*) in relation to their experiences of stroke-related perceptual disorders. We wanted to maximise the usefulness and application of these findings to current stroke clinical practice and future research activities.

Researchers and stakeholders shared their understanding of the findings in a facilitated discussion [see *Stakeholder activities (what happened)*, Activity 5] to draft the implications for (1) stroke survivors and carers and (2) clinicians and policy-makers [see *Stakeholder activities (what happened)* and *Report Supplementary Material 6*]. The stakeholder group and research team also sought consensus on the top priorities for future research relating to perceptual problems after stroke, via a group discussion followed by an individual ranking process [see *Stakeholder activities (what happened)*, Activity 6 and *Report Supplementary Materials 7* and *8*].

Implications for stroke survivors and carers

Stakeholders with lived experience (n = 3) expressed disappointment at the lack of evidence underpinning stroke-related perceptual disorder interventions and highlighted the need to:

- Provide more information to stroke survivors about any perceptual disorders they have. They also recommended that this information be shared with a family member/carer to support the stroke survivor, facilitating their understanding and information retention.
- Improve awareness and understanding of perceptual disorders following stroke among the public and HCPs involved in stroke care. This was considered particularly important for younger stroke survivors, who may not receive the same level of post-stroke support.
- Provide regular, one-to-one support, tailored to the needs of the individual with perceptual disorders after stroke; opportunities for stroke survivor and carers to meet and talk with others affected could help address the associated psychological and emotional impacts.

In addition, the members highlighted that while most recovery occurs in the first few months post stroke, that progress can continue over much longer time periods.

Implications for clinicians

Members of the Clinical Expert Group and research team (n = 6) identified seven broad clinical implications relating to stroke survivors with perceptual disorders (see *Report Supplementary Material 6* for sense-specific suggestions made).

Healthcare professionals should:

- Be aware that perception may change following a stroke.
- Ask about perception in their healthcare assessment appointments.

- Ask about the everyday impacts of any perceptual disorders.
- Be open about the lack of evidence underpinning interventions (being clear that this does not mean that nothing works).
- Consider use of routine or simple interventions, rather than focusing only on interventions identified in the reviews, for example if hearing perception problems, write things down (where appropriate given other abilities).
- Approach a patient holistically, considering perception in relation to their other abilities and/or disorders and in relation to individual's goals, when choosing an intervention. For example, if a patient's perceptual disorder is primarily causing practical difficulties in everyday life, the intervention chosen may be different from someone in which the perceptual disorder is primarily causing psychological distress.
- Develop their knowledge about interventions for stroke survivors with perceptual disorders after stroke.

Implications for policy-makers

The stakeholder group and researchers discussed the implications for policy-makers. There was considerable overlap between what was considered important for policy-makers, and the implications for clinicians (see *Implications for clinicians*) relating to the need for person-centred care, awareness, education, information, screening/assessment and an enhanced evidence base (see *Report Supplementary Material 6* for full list). The following points were noted as of specific importance to policy-makers:

- Interventions for perceptual disorders after stroke are a specialist area requiring adequate numbers of appropriately trained clinical and support staff.
- Where stroke survivors with perceptual problems are inadequately supported, there will likely be associated healthcare, societal and personal economic impacts.
- International stroke clinical guidelines should address the assessment of and interventions for perceptual disorders after stroke regardless of whether current evidence levels are sufficient to inform practice. Guideline developers should consider qualitative evidence, including patient stories and best practice statements.
- Stroke survivors with perceptual disorders who are independent may still require services that provide practical care and support.

Research priorities

Thirteen members of the Lived Experience Group, Clinical Expert Group and research teams discussed and agreed nine research gaps relating to perceptual disorders in stroke. In addition, sense-specific research questions were drafted.

The nine research gaps were ranked. Three Lived Experience Group, four Clinical Expert Group and eight researchers participated. These individual rankings (minimum possible score = 1, representing highest priority) were summed to create a prioritised list (*Table 10*).

See *Report Supplementary Material 7* for sense-specific research recommendations (7 vision; 10 somatosensory; 9 touch/tactile, 11 taste and smell and 8 hearing), and *Report Supplementary Material 8* for the research priorities wording and summed scores.

Summary

Working in partnership with our Lived Experience and Clinical Expert Groups, we integrated the findings from the scoping review (see *Chapter 5*) and the Cochrane systematic review (see *Chapter 7*) to coproduce the clinical implications for stroke survivors, clinicians and policymakers. We also coproduced and prioritised the research gaps with the top research priority identified as the need to explore the lived experience of stroke survivors with perceptual disorders, and their carers.

TABLE 10 Research priorities for perceptual disorders in stroke

Rank	Research gap
1	**Explore the lived experiences of stroke survivors and carers** • What is the impact of perceptual problems on daily lives? • What is their understanding of their perceptual problem? • What is most important to stroke survivors and carers? • What support services do they need? • What are the long-term impacts of perceptual disorders after stroke?
2	**Enhanced assessment of perceptual problems following stroke** • What is the best way to assess perception (including in stroke survivors with concomitant impairments, e.g. cognitive, communication or other health issues)? • What is the best way of distinguishing between perceptual problems and other problems (e.g. sensory, cognitive)? • How, and to what extent, do perceptual problems impact on function? • What is the relevance, validity and reliability of clinical assessments and outcome measures used in research?
3	**Pragmatic exploration of interventions, which reflects the experiences and needs of stroke survivors, and clinicians' perspectives** • Using or creating outcome measures (of effectiveness) that reflect stroke survivors' priorities • Exploring interventions currently in use, or readily accessible to clinicians • Exploring intervention/service costs • Exploring feasibility, acceptability and sustainability • Conducting research in all relevant populations and considering comorbidities
4	**Establish current practice for perceptual disorders after stroke** • What is 'usual care' (including long-term care) provided to stroke survivors with perceptual problems? • What interventions are currently delivered in the 'real-world', and what is the nature of these interventions?
5	**Establish the prevalence of perceptual problems following stroke** • What is the frequency (prevalence) of perceptual problems after a first stroke? • What is the frequency of perceptual problems after a second or subsequent stroke? • Exploring patterns of natural recovery, including long-term recovery, from perceptual problems • Exploring the relationship between perceptual problems and other stroke-related impairments
6	**Explore current care delivery and pathways, across NHS, social care and charities** • Who is providing care? • What care/services are provided? • When and where are care/services provided? • When and how are referrals to specialists made? • Are there clear pathways and plans for care for perceptual problems? • What is the acceptability of care delivery to stroke survivors and carers?
7	**Explore the impact of perceptual impairment on the family and carers** • What is the impact on children of stroke survivors? • What do family members *provide* by way of support for individuals with perceptual problems? • What is the impact on family members and carers of providing support to individuals with perceptual problems, for example caregiver strain, depression, QoL?
8	**Establish the best ways of providing education, and ensuring adequate knowledge and understanding of professionals** (including those working in health and social care, and in charity/third sector organisations)
9	**Research to establish a clear definition of perception** This may include work to determine clear definitions and names (terms) for perceptual disorders

Chapter 9 The impact of stakeholder involvement

Introduction

This chapter considers the impact of stakeholder contributions to the PIONEER project, providing an overview of involvement activities, how these impacted on the project and the level of involvement achieved. We reflect on strengths and weaknesses of our approach.

Who was involved?

Our Lived Experience Group included two stroke survivors with perceptual disorders after stroke and three carers of stroke survivors with perceptual disorders: one carer left in month 22/24 of the project. Our Clinical Expert Group included two experts in visual perception, one in hearing, and one in taste and smell. This expertise was supplemented by Research Team members with clinical expertise in stroke and or perceptual problems including touch and somatosensory perception.

Stakeholder activities

The Lived Experience and Clinical Expert Group members contributed to decisions across six activities [see *Stakeholder activities (what happened)*] with the results of these activities reported in the relevant sections (see *Types of participants: defining perception*, *Types of outcome measures*, *Interpretation of scoping review results*, *Interpretation of Cochrane Review results*, *Implications for stroke survivors and carers*, *Implications for clinicians*, *Implications for policy-makers* and *Research priorities*; an overview of these activities is given in *Table 11*).

Evaluating stakeholder involvement

We aimed to capture the nature and level of involvement from the stakeholders' perspectives (see *Evaluation of impact of stakeholder involvement*); these were collated and researchers graded the level of involvement.[103]

Definitions of key terms (level of involvement: controlling)

Lived Experience Group members described the terms used to define perception as 'complicated jargon', saying that 'it was like a complex vocabulary … that's not really something I've come across…'.

Outputs included an agreed definition of perception ('specific mental functions of recognizing and interpreting sensory stimuli'), lay definition of perception ('processing and understanding information from the senses'), definitions of included senses, inclusion criteria in relation to specific (complex) disorders and detailed list of perceptual disorders.

Impact on the project: Definitions agreed by the stakeholders were applied throughout the review, including in the search strategy, selection of studies, data synthesis and interpretation of findings. Lists of disorders were used to inform the search strategy.

Despite the development of a lay definition of perception, definitions of each individual sense, provision of a glossary for each project activity, and a concerted effort by the research team to use simple

TABLE 11 Summary of stakeholder involvement and activities

Activity	Stage of review	Who took part (*n*=)		
		Lived Experience Group	Clinical Expert Group	Research team
One-time involvement activities				
1. Definitions of key terminology	2. Plan methods 4. Develop search 6. Select studies	2	3	9
2. Outcome measure prioritisation	2. Plan methods	5	3	8
3. Interpretation of scoping review results	9. Analyse data 10. Interpret findings	5	4	7
4. Interpretation of Cochrane Review results	9. Analyse data 10. Interpret findings	4	1	11
5. Clinical implications	10. Interpret findings 11. Write and publish review	2	2	8
6. Research recommendations	10. Interpret findings 11. Write and publish review	3	4	11
Continuous involvement				
Project oversight	All stages	5	4	11

language throughout, Lived Experience Group members repeatedly found it challenging to recall and to understand many of the terms when they were used throughout the project.

Outcome measure prioritisation (level of involvement: influencing and controlling)

There was general agreement between Lived Experience Group, Clinical Expert Group and researchers on the 'Top 10' most important outcome measures. However, there were variations in the specific rankings, with stakeholders placing greater priority on social activity and participation. The inclusion of outcome measures within the scoping review and the selection of outcomes for the Cochrane systematic review provided clear evidence that the stakeholders had an impact on the reviews; the use of specific outcomes within the review is summarised in *Table 12*.

Outputs: List of impact of perceptual impairment on daily life, prioritised list of outcome measures.

Impact of activities: A prioritised list of outcome measures was agreed. This directly informed the selection of outcome measures for inclusion in the scoping and Cochrane Reviews.

Stakeholders were pleased with their contribution to outcome measurement prioritisation 'It's good news that what we're seeing is embedded in what's been done'. They queried whether the reviews sufficiently addressed the emotional impact of living with perceptual problems after stroke: 'I'm not sure that we explored the emotional impact, as much as perhaps we needed to, because it is very important… '.

Interpretation of review findings, implications and research recommendations (level of involvement: contributing, influencing and controlling)

Stakeholders expressed disappointment at the small number of studies, evaluating interventions which did not reflect 'real-world' experiences. They urged collaboration between clinicians and researchers to identify and evaluate clinical practice for patients with perception problems.

TABLE 12 Prioritised outcome measures and representation within PIONEER reviews

Prioritised outcome measures	Scoping review	Cochrane Review
1. Performance in ADLs	✓	Primary outcome
2. EADLs	✓	Secondary outcome
3. Social activities and participation	✓	(Incorporated into QoL outcome)
4. Psychological well-being and mental health	✓	Secondary outcome [(1) stroke survivors, and (2) family, friends and carers]
5. QoL	✓	Secondary outcome [covering (1) QoL scales, (2) social activities and participation scales, (3) mobility, navigation and safety scales]
6. Mobility navigation and safety	✓	(Incorporated into QoL outcome)
7. Sensation, cognition, motor ability, attention	✓	Noted, but not analysed
8. Impact on rehabilitation	✓	
9. Perceptual function	✓	Secondary outcome
10. Impact on family, friends and carers	✓	(Incorporated into psychological well-being and mental health outcome)
11. Paediatric – measures of development, education	✓	
12. Discharge destination	✓	
13. Feasibility, acceptability, etc.	✓	
14. Adverse events	✓	Secondary outcome
15. Compensation using other skills	✓	
16. Neurological function	✓	
17. Economic outcomes	✓	

Outputs: Interpretation of the meaning of the scoping review and Cochrane Review findings, list of clinical implications, prioritised list of research gaps.

Impact of activities: The stakeholders raised several key issues relating to the meaning of the scoping review and Cochrane Review results. These points influenced the writing of the review findings and discussion. The stakeholders agreed lists of implications which have been incorporated into the findings from this project and reached a shared consensus on a prioritised list of research gaps (see *Chapter 8*).

Few stakeholder feedback forms were returned after these activities, perhaps due to frequency of project meetings and time commitments which may have been exacerbated by pandemic-related challenges (see *Limitations*). Despite the lack of feedback forms, stakeholders spoke passionately about the importance and potential impact of their input:

> *I really would like to think that something would come out of this study, in terms of just getting basic things at the beginning when somebody has a stroke …*

Members of the Lived Experience Group emphasised that getting these 'basic things' right for people with perceptual disorders after stroke could have a big impact on an individual's life, such as early

assessment and diagnosis facilitating access to the right support, for example a bus pass for someone with visual issues struggling with mobility and transport.

Reflections on involvement

The Lived Experience Group reported that they found their involvement:

- **Interesting:** '*I think is interesting to find out … listening to the data, what the results are, and what have you, compared to … myself*'.
- **Rewarding:** '*for me, it's always rewarding*'.
- **Relevant:** '*I don't think for one moment we've had any topics which hadn't been relevant to the project*'.
- **Supportive:** '*It's good to hear other people's experience*'.
- **Educational:** '*I opened my mind to not only the impairments of how it's affected me and my family, but others*'.

Challenges were described due mainly to the online meeting format:

- **Practical problems relating to stroke impairment:** '*I did have some problems with some of the charts, and the way that some of the information was laid out and screen. … That was quite difficult for me. And obviously that's because [of] my vision,….*'
- **Lack of face-to-face interaction:** '*had it been non-COVID times it would have been much better, as we'd actually have been able to meet. Well, Zoom, and the like types of meetings are good, they're not the same as face-to-face interaction.*';
- '*….it's been a bit of really hard battle to actually do anything and everything was online … you don't get that personal touch … you don't pick them up on the body language. You know, for me, it's difficult. … But, face to face I'm happy with*'.

In addition, the complexity of perception terminology posed an ongoing issue: 'I've tried to simplify things a bit, and I've struggled with the way that certain things have been worded…'. In relation to the complexity of the concept of 'perception', the research team reflected that it may have been beneficial to have started each meeting with a reminder of the agreed lay definitions.

When asked what they would change in order to improve their experiences of involvement, stakeholders made a number of suggestions, many of which related to the perceived benefits of face-to-face meetings:

- **Making sure people know one another:** '*when we meet face to face … I think it also helps people to really understand who's part of the group, I'm still struggling to understand and remember who's who, because the group's been quite big. And, I think when you don't know people… It can be quite difficult to try and speak*'.

Building on this, stakeholders suggested that it may be helpful to have a '*pre-meeting of patient and public involvement (PPI) members … without too many academics being around*', to allow stakeholders to share experiences.

- **Support for online meetings:** '*some of us aren't very computer literate…*'
- **Clear explanation of why stakeholder involvement is required:** *someone could perhaps … say 'look, we can't do this without you. And the reason we can't do this without you is because we don't have any experiences. We need you to lead us*'.
- **More regular and detailed feedback after each task:** '*it would be helpful for us who contributed PPI to know how we have actually influenced your research and how we have, perhaps, enlightened you to things that you weren't aware of. We get so little feedback at times*'.

Summary

Our multifaceted stakeholder approach involved a co-applicant with lived experience, a group of people with lived experience and HCPs with clinical expertise relating to stroke-related perceptual problems. These stakeholders coproduced the review including having control and influence over some specific aspects. Areas of the review in which stakeholders had a demonstrable impact included: the key terminology, outcome measures and recommendations for research; interpretation of findings and clinical implications of the results. Stakeholders perceived their involvement as interesting, rewarding, relevant, supportive and educational.

Chapter 10 Confidence in evidence

Introduction

In this chapter, we summarise the findings of the PIONEER project across the scoping review, the Cochrane systematic review revision, expansion and update and research prioritisation process. We consider the methodological quality of the two reviews, including the risk of bias in our project design, delivery or interpretation of findings and confidence in our findings.

Scoping review

Our review scoped the breadth and nature of intervention research to date relating to perceptual disorders after stroke. We identified 80 studies (893 participants); these primarily explored visual (*n* = 357) or somatosensory (*n* = 303) perceptual problems, frequently using a case report (36/80) or RCT (2/80) design. The most frequent intervention approach was rehabilitative, often targeting restitution of ability in the impaired function. Pharmacological and NIBS interventions were also identified. Interventions involved training by an HCP, as well as the use of technical or robotic devices, and other specialist equipment. Interventions were most frequently delivered in hospital, for up to 4 weeks, involving one-to-one training with a therapist (as opposed to group or self-delivery techniques). Perceptual and motor/sensorimotor skills were the most common outcomes reported. Priority outcomes, such as ADLs and the impact on social participation, psychological well-being and mental health were rarely reported. Few studies captured outcomes beyond initial post-training effects. Clear evidence gaps were highlighted (see *Figure 8* and *Table 13*).

Cochrane systematic review

The Cochrane Review examined the effectiveness of stroke-related perceptual disorder interventions. Based on 18 included RCTs (*n* = 541), 3 RCTs examined interventions for tactile disorders (*n* = 70), 1 examined interventions for somatosensory disorders (*n* = 194), 7 considered interventions for visual perception disorders (*n* = 225), 1 investigated mixed tactile–somatosensory disorders (*n* = 50). Interventions for hearing, smell or taste perceptual dysfunction were not identified (see *Table 13*).

Interventions for somatosensation perception disorders

We found low-certainty evidence of no difference between interventions and control on measures of ADLs, navigation and mobility. We found low-certainty evidence of no difference between two interventions for somatosensory perception dysfunction (not Pusher syndrome) on perception outcomes. For Pusher syndrome, we found low-certainty evidence of no difference between game-based posture training and standard physiotherapy for measures of mobility and navigation and perception. We also found low-certainty evidence suggesting that game-based posture training for Pusher syndrome may be more beneficial than standard physiotherapy for improving ADLs and measures of Pusher syndrome severity (see *Table 13*).

Interventions for touch perception disorders

We found low-certainty evidence that there is no difference between intervention and no treatment for navigation and mobility outcomes, but there may be a beneficial effect of active intervention on perceptual function. Evidence relating to one intervention versus another was varied, and insufficient to draw generalisable conclusions (see *Table 13*).

TABLE 13 Summary of findings for scoping review and Cochrane Review

Scoping review: 80 studies, 893 participants						
Perceptual disorders		**Vision** *n* = 357 (40%)	**Somatosensation** *n* = 303 (33.9%)	**Hearing** *n* = 33 (3.5%)	**Tactile** *n* = 107 (11.9%)	**Mixed** *n* = 93 (10.4%)
		Visual–spatial deficit 35 (10%) Visual hallucination 8 (2%) Visual agnosia 3 (1%) 'Other' visual perceptual disorder 37 (10%) Unspecified 274 (77%)	Pusher syndrome 232 (77%) Proprioceptive deficits 14 (5%) 'Other' somatosensory deficit 57 (19%)	Auditory processing disorder 32 (97%) 'Other' hearing disorder 1 (3%)	Tactile dysfunction 107 (100%)	Tactile-somatosensory disorder 68 (73%) Taste–smell disorder 1 (1%) Vision–tactile disorder 24 (26%)
		Interventions = 37	Interventions = 35	Interventions = 7	Interventions = 7	Interventions = 7
Interventions descriptors (most frequent response)	**Class** **Materials** **Who delivered**	Rehab (restit) 15 (41%) HCP-led 12 (32%) NR 18 (49%)	Rehab (restit) 24 (69%) HCP-led 17 (49%) NR 17 (49%)	Rehab (subst) 4 (57%) Technology 5 (71%) NR 4 (57%)	Rehab (restit) 4 (57%) Special. equip 4 (57%) NR 5 (71%)	Rehab (mixed) 4 (57%) Special. equip 5 (71%) NR 5 (71%)
	Mode **Location**	One-to-one 25 (68%) Hospital inpatient 15 (41%)	One-to-one 32 (91%) Hospital inpatient 18 (51%)	One-to-one 5 (71%) Hospital (unclear) 3 (43%)	One-to-one 7 (100%) Hospital (unclear) 3 (43%)/NR 3 (43%)	One-to-one 7 (100%) NR 7 (100%)
	Overall duration	NR 19 (51%)	< 1 month 17 (49%)	1–3 months 3 (43%)	< 1 month 2 (29%)/ NR 22 (29%)	NR 5 (71%)
Cochrane systematic review: 18 RCTs, 535 stroke survivors, 20 comparisons						
Studies		**Visual**	**Somatosensation**	**Hearing**	**Tactile**	**Taste or smell or mixed**
		7 RCTs (*n* = 225)	7 RCTs (*n* = 196)	No RCTs	3 RCTs (*n* = 70)	No RCTs
Interventions		*Interventions* 11 Restitution 1 Restitution-compensation	*Interventions* 10 Restitution 2 Restitution-substitution 1 NIBS	No RCTs	*Interventions* 4 Restitution 1 Restitution-substitution	No RCTs

TABLE 13 Summary of findings for scoping review and Cochrane Review (*continued*)

Scoping review: 80 studies, 893 participants						
Meta-analysis (ADLs outcome)	**Intervention vs. no treatment**	No RCTs	No RCTs	No RCTs	No RCTs	No RCTs
	Intervention vs. control	No RCTs	MD 10.08 (−2.47 to 22.63) 1 RCT; *n* = 24 non-Pushers syndrome very low[a,b,c]	No RCTs	No RCTs	No RCTs

n, participants represented; NR, not reported; rehab, rehabilitation; resitut, resitution; special., specialist; substit, substitution.
a GRADE at least one RoB category is high or uncertain.
b Very small number of participants/studies (two downgrades).
c Baseline differences between groups.

Interventions for visual perception disorders

We found low-certainty evidence of no difference between intervention and no treatment on measures of perception; there was no difference between active intervention and control for measures of EADLs. We identified some data for outcomes of ADLs, navigation and mobility and perception from RCTs comparing one intervention to another. Due to differences in the interventions and comparisons, the data were not statistically pooled, and it was not possible to draw generalisable conclusions (see *Table 13*).

Overall, there is insufficient evidence to determine the effectiveness of any one intervention for any sensory modality, nor the effect of one intervention relative to another.

Prioritisation process

The stakeholder groups and research team collectively generated the research priorities relating to perceptual disorders after stroke. The top five research priorities highlighted the need for further research to (1) explore the lived experience of people with stroke-related perceptual disorders, (2) improve assessments of stroke-related perceptual disorders, (3) explore interventions in a way that reflects real-world needs, (4) explore clinical practice to address perceptual disorders following stroke and (5) establish the prevalence of perceptual disorders after stroke (see *Chapter 8*).

Methodological quality of the research identified

The research literature relating to perceptual disorders was reviewed using a scoping review followed by a Cochrane systematic review. Using recognised scoping review methodology,[94] a detailed search strategy identified a broad range of research designs, perceptual disorders, interventions, outcomes and healthcare settings. Neither a research quality filter nor an appraisal of research quality was applied to the 80 studies identified. Instead, the high proportion of single-participant studies, the small number (27.5%) of randomised controlled RCTs and the absence of reported stakeholder input were highlighted.

The subsequent Cochrane systematic review included a formal quality appraisal of 18 RCTs identified. Random sequence generation was unclear for five RCTs with concealment of allocation was unclear for two-thirds of the included RCTs. Blinding of outcome assessors was at a high risk of bias or unclear bias in all RCTs. Attrition and reporting bias was low but sample sizes were small (see *Figure 10* and *Report Supplementary Materials 14* and *21*). Thus, the RCTs contributing to the Cochrane systematic review and meta-analysis were at high risk of bias.

Meta-synthesis and risk of bias

With reference to the ROBIS tool[253] we considered to what degree our scoping and Cochrane systematic reviews were at risk of systematic limitations resulting in a risk of bias and the extent to which these may have impacted on our conclusions.

Study eligibility criteria – selection biases

The PIONEER sequential review process had two research questions and different eligibility criteria. Conducted consecutively, the scoping review used very broad studies inclusion criteria to provide an overview of the topic area (see *Chapter 4*) while the Cochrane systematic review narrowed these selection criteria to focus on the RCT data (see *Chapter 6*). Both reviews were based on a thorough and up-to-date systematic search strategy developed by an information specialist and informed by research and clinical experts. Contact was made with leaders in the field and forward citation tracking was also used. Between the scoping and Cochrane Review, the search was updated to ensure that no emerging

trials were omitted between the scoping review's last search date and the start of the Cochrane Review process.

In the complex context of perceptual disorder research, we drew on existing definitions of perception (WHO)[7,8] and working with our stakeholder groups, and these were expanded and operationalised to create subcategories by sense (visual, auditory, tactile, somatosensory, smell and taste) to support the planned reviews (see *Chapter 3*). We acknowledge that alternative definitions and categorisations could have emerged and in turn could have impacted on the identification of studies and the inclusion of additional or alternative research in the reviews. However, our consensus use of WHO definition[7,8] was agreed by people with lived experience of perceptual disorders after stroke, and by multidisciplinary healthcare and research groups and thus were ideally suited to address our research questions. This ensured that all study eligibility decisions were consistently made across reviews, and thus unlikely to have introduced systematic limitations.

Both reviews used unambiguous, appropriate a priori eligibility criteria with no restrictions on the language, date or location of the study. The scoping review applied no restrictions to study design, perceptual disorders, interventions or outcome data considered eligible, reflecting the nature of the scoping review objectives. Qualitative study designs were eligible, but none were identified.

The Cochrane systematic review added three additional restrictions to the eligibility criteria used by the scoping review; only RCT data were included reflecting the Cochrane Review research questions, only adult participants were included, and a smaller number of outcome measures were included.

Both reviews focused on participants with stroke-related perceptual disorders; studies with a population where at least 80% had stroke-related perceptual disorders were also included. The scoping review included eight such mixed-sample studies [24 participants (2.6%) without a perceptual disorder or non-stroke-related perceptual problems]. Almost all (98.9%) of Cochrane Review participants experienced stroke-related perceptual disorders – one study included six participants with perceptual disorders following head injury. Throughout, we accepted the primary research diagnosis of perceptual disorders following stroke.

Data identification and selection – availability bias

In conjunction with a trained information specialist (JC) and informed by the stakeholder groups, we undertook detailed and exhaustive search of published and grey literature electronic databases (including hand searching) and forward/backward citation tracking (see *Appendix 1* and *Report Supplementary Material 9*) to identify all relevant research to inform the scoping and subsequent Cochrane Review. The strength of this approach was the initial broad, inclusive, comprehensive search strategy supporting the scoping review. This was later narrowed using a RCT methodological filter to inform the Cochrane systematic review (see *Appendix 3* and *Report Supplementary Material 13*). Application of methodological filters is known to increase the risk of omitting relevant studies,[254,255] but our initial broader scoping review search guarded against this risk. All searches used free-text and subject index terms, reflecting the population, disorder and intervention. While it is possible that relevant research remained unidentified, we made every effort to identify it and include it in our reviews.

The data identified research conducted across the world, across disciplines and languages, over publication time points and stroke chronicity and across various subject topic areas and countries. Data eligibility criteria were applied by independent members of the research team at abstract and full-text stage. Grey literature was screened by a single member of the research team with decisions carefully checked by a second team member. Where disagreements were unresolved through discussion, a third team member or a Clinical Expert Group member was consulted.

Data collection and appraisal

Our structured Excel-based data extraction tool, underpinning the scoping review and Cochrane systematic reviews was independently piloted by two reviewers; the data extracted were compared and tool discussed and refined before it was used. All potentially relevant data were extracted. Data were extracted by one researcher and carefully checked by a second. Where clinical details were ambiguous, we involved a member of the Clinical Expert Group in decisions. Data synthesis, extraction items and categorisation used reflected published definitions. For RCTs, the data were extracted and directly entered into RevMan but were carefully checked by a second reviewer. The Cochrane Review risk of bias appraisal was undertaken by two independent researchers.

Synthesis and findings

Data restrictions

The scoping review and Cochrane systematic review methodology supported a broad and inclusive review of the stroke-related perceptual disorder literature, but the data extraction was restricted to that reported in the literature. Research teams were only contacted where it was not possible to determine inclusion based on the published data. The subsequent Cochrane Review methods included some data gathered via direct contact with the included trialists (2 of the 18 included trials data reflect information gathered from unpublished communications) (see *Chapter 7*). One trial reported only partial outcome data[234] (MOCA, nine-hole peg test and functional magnetic resonance imaging) and a second trial described collection of secondary outcomes, but data were not available.[74]

Eleven trials were classified as awaiting classification. Due to a lack of clarity of reporting it was not possible to confirm that studies met inclusion criteria in relation to the disorder (n = 6), method (including randomisation process) (n = 2) or more than one inclusion criteria (n = 3). In each case we attempted to contact the author but received no reply.

Publication bias

Funnel plot analysis to assess the risk of publication bias is not typical in scoping review methodology, and there were insufficient data within the Cochrane Review to support this analysis (see *Chapter 7*). Generally, identified data sets were based on small sample sizes; predominately single-participant within the scoping review and only two RCTs randomising ≥ 50 participants, raising some questions about the quality of the data available.

Age of data sets

Of the data sets included within the scoping review, 63.7% (51/80) were published since 2010 with 34 (42.5%) of these published since 2015. Most trials (13 RCTs) included in the Cochrane Review were published in the last 5 years (2015–21); the remaining 5 were published between 2012 and 1985 and included the 2 largest trials in the review (n > 50).

Origin of data sets

The data sets included in the scoping and Cochrane systematic reviews reflect international research efforts. Research identified in the scoping review emerged from Asia, Europe, North America, South America and Australia. Within the Cochrane systematic review, the trials were conducted in Australia, Belgium, Germany, South Korea, Taiwan, UK and USA.

Data synthesis

Scoping review data were classified and organised by the perceptual disorder addressed and intervention assessed (subclassified by approaches used). Categories were pre-specified and agreed with the stakeholder groups as were the outcome measures of interest in the review. This was a complex task – difficulties in categorising interventions (especially where there was lack of reporting) were addressed by having a third reviewer, who was provided with clear definitions of intervention approaches,

categorise all interventions. Further specialist input relating to Pusher syndrome interventions was provided by a somatosensory expert. Data were tabulated and presented using standard Word or Excel tables and an interactive visual map which were positively received by the Lived Experience Group members. The Cochrane Review interventions were organised in a similar manner, by perceptual disorder and intervention approach (with rehabilitation approaches subclassified).

In the Cochrane Review we followed pre-specified analyses as described in our protocol, registered with PROSPERO (CRD42019160270) and NIHR's website [https://fundingawards.nihr.ac.uk/award/NIHR128829 (accessed November 2022)] and pooled trial data that compared active interventions with no treatment/control/alternative intervention. We used a random effects model (RevMan 5.4) to support statistical analysis. Our planned sensitivity analyses included exploration of the use of a fixed-effects model, but the lack of data prevented this and other planned sensitivity and subgroup analyses.

The populations represented in the scoping and Cochrane Reviews spanned the clinical trajectory of stroke-related perceptual disorders (acute to chronic) and we sought (but did not always identify) a wide range of perceptual disorders, interventions and outcomes. A small number of participants included in both the scoping and the Cochrane Reviews were recruited to mixed study populations; they did not have perceptual disorders or their perceptual disorder was not stroke-related. Given the overall lack of data availability and overlap of the available data, it is highly unlikely that an alternative approach to data synthesis would alter our findings.

Across the included trials, however, biases were evident in the RCTs, particularly in relation to the randomisation process, blinding and inadequate outcome reporting (described above). Most biases were related to inadequate reporting, though a third of trials were considered at high risk of detection bias due to an absence of outcome assessor blinding.

Reporting the results

The scoping review data were identified and tabulated using pre-specified scoping review framework[94,114,115] and a recognised classification system[8,124,125] (see *Chapter 4*). Included information was presented in an accessible format, by study design, population and intervention component, profiled in graphs and numeric summaries. We compared the scope and levels of evidence and research gaps. Similarly, the Cochrane systematic review reported the findings in keeping with the Cochrane methodological requirements,[222] adhering to a pre-specified and accessible protocol, and profiling the identified trial data by comparison, intervention versus (1) no treatment, (2) control/placebo or sham and (3) another intervention.

Quality of evidence

No measure of quality was applied to the scoping review identified data (see *Chapter 5*). A judgement of the quality of evidence included within the Cochrane was made using the GRADE approach and found the evidence from meta-analyses to be of very low certainty (see *Chapter 7*) due primarily to risk of bias, imprecision and indirectness.

A rigorous two-stage review approach, however, enabled a broad scope of the literature followed by a Cochrane systematic review and meta-analysis where possible, of the trial data. This ensured that the most comprehensive and methodologically rigorous approach to data synthesis was carried out. The lack of consensus on definitions and outcomes to date was particularly striking, impacting in turn on the quality and disparities across the emerging evidence. Coproduced definitions of perceptual disorders, the senses addressed and outcomes considered most important to people with perceptual disorders, their families and their HCPs, underpinned our review methodologies. The trials identified reflect the

recently emerging international research focus on perceptual disorders after stroke, the historical lack of research activity (particularly large-scale studies) and the many research gaps in the senses that we considered. These challenges were unrelated to our pre-specified review methodologies and ensured that our research team did not introduce biases during the data synthesis approaches.

Heterogeneity and inconsistencies

Across both reviews we identified data availability issues: the high number of studies involving a single participant, small sample sizes in group studies, the lack of RCTs and the gaps in availability of hearing, smell and taste perceptual disorders intervention research. With limited data to date, between study variation and inconsistency, clinical or statistical heterogeneity were less apparent.

Missing data/missing completely at random

In the scoping review we did not contact authors for any missing data; data extracted were based on the information contacted in published articles. Where data were missing from RCTs remained unavailable, we used presented data to calculate the missing data using standard methods.[222]

Sensitivity analyses

Our scoping review did not include any formal meta-analysis or sensitivity analysis of the data identified. Sensitivity analyses using the ADLs primary outcome data were planned in the context of RCTs identified in the Cochrane systematic review: high/low risk of selection bias, performance bias, detection bias, attrition bias, reporting bias and 'other' sources of bias. The paucity of data and limited overlap in the available data prevented any planned sensitivity analysis. Only RCTs were eligible for inclusion in the Cochrane systematic review.

Summary

The evidence base informing interventions for perceptual disorders after stroke is very limited and what was identified and available is focused on a selective group of perceptual disorders, with typically small sample sizes and non-RCT study designs. Our PIONEER study used a two-stage review approach: a broad scoping review followed by the narrower eligibility criteria of the Cochrane Review (see *Chapters 4* and *6*). Our review methodologies made every effort to reduce the risk of bias in the review and meta-analysis processes, reducing the risk of selection and availability of meta-bias. Biases were evident in the primary research data. The paucity of data limited our planned examination of heterogeneity, sensitivity and subgroup analyses. Our reviews suggest the topic of perceptual disorders after stroke has been neglected in the literature to date, with the more recent emergence of small pilot RCTs in the last 5 years addressing selected perceptual disorders.

Chapter 11 Discussion and conclusion

Introduction

In this chapter we discuss the findings of the PIONEER project in relation to existing literature, consider the strengths and limitations of these findings, and their implications for researchers and clinicians.

Summary of findings

The PIONEER scoping review mapped the available evidence base relating to interventions for perceptual disorders after stroke in adults and children (see *Chapter 5*), finding few reports of interventions for hearing, taste, touch or smell perceptual disorders. Research reports described single case studies and, to a lesser extent, RCTs. The 80 studies identified focused primarily on rehabilitation interventions for visual and somatosensory perceptual disorders after stroke. Descriptions of participants and interventions were incomplete and qualitative data on stroke survivors' experience of perceptual disorders and interventions were absent.

Our Cochrane systematic review update explored evidence of the effectiveness of interventions for perceptual disorders after stroke (see *Chapter 7*). We compared interventions to no treatment, or a control group that received a placebo, standard care or an attention control. We measured benefit based on participants' ADLs. No RCT evidence on the treatment of hearing, smell or taste perceptual disorders following stroke was identified. While there was some evidence relating to interventions for somatosensation, touch and visual perceptual disorders, there was not enough to support any one intervention.

The Lived Experience and Clinical Expert Groups were disappointed in the quality and quantity of evidence informing the treatment of people with perceptual disorders after stroke. The groups identified key clinical implications including the provision of information about perceptual disorders to stroke survivors, their family and carers, the need to improve awareness, the importance of early, accurate diagnosis and having a holistic approach to care provision. The stakeholders generated research priorities relating to definitions, assessment, impacts, interventions, services and HCP training relating to stroke-related perceptual disorders. The breadth of future research required reflects the current paucity of research into this topic area.

Previous perceptual disorder reviews

Our Cochrane systematic review significantly expanded the scope of a pre-existing review[6] to include all interventions targeting six sensory domains, while ensuring it focused on a stroke aetiology. While we identified 18 RCTs compared to the 6 RCTs included in the 2011 review, our conclusions are broadly similar, as clinical intervention remains poorly supported by high-quality RCTs.

Several additional Cochrane Reviews address related disorders such as sensory and sensorimotor function,[9,256] visual neglect or attention[10] and stroke-related cognitive disorders:[111,257,258] these identified limited RCT evidence to support clear conclusions on intervention effectiveness. Nevertheless, these syntheses are a source of additional information for clinicians. Additional, non-Cochrane intervention reviews have potential relevance for disorders of visual perception,[88,259] and touch and somatosensation.[47,89,260,261]

Jutai (2003), in their narrative summary relating to perceptual impairment, neglect and apraxia [six RCTs and two cohort studies (*n* = 373)], concluded that there was strong evidence that transfer of training improved perceptual function. However, our RCT meta-analysis findings have resulted in a different conclusion. A series of systematic reviews (and updates) including literature up to 2014 included 'visuospatial functioning' – focusing on visual neglect (10/13 studies), making no recommendations relevant to perceptual disorders as defined in our review.[262] Hanna's review[259] of vision interventions included perception, but again mainly focused on neglect, with studies included in that review falling outside of our inclusion criteria.

Four reviews considered interventions relating to touch and somatosensation disorders after stroke. A 2009 paper on retraining sensation after stroke,[89] updated in 2019[260] to include 38 RCTs (1093 participants) with meta-analysis of data (13 comparisons). The updated review defined sensation as the ability to 'detect and discriminate objects and textures, know where our body is in space (proprioception) and accurately perceive and discriminate sensations of pain, temperature, pressure, and vibration', and explored sensory retraining [passive (externally applied stimulation), active (sensory retraining of graded re-education) or a hybrid]. They found limited data, with some evidence to support passive sensory techniques, but the effect of active techniques was unclear. Similarly, a review of 13 RCTs addressed 'sensory registration, perception, or discrimination', impairment specific to the upper limb, with a focus on outcome measures of sensation.[47] Specific sensory inclusion criteria were unclear in this review, and inclusion appeared to relate to the presence of hemiplegia. They found insufficient evidence to reach conclusions about the effects of included interventions. Clear differences exist in the populations included in these reviews and our Cochrane systematic review including the (1) nature of the intervention, (2) body part considered and (3) nature of the disorder addressed. Our review inclusion criteria required a clear diagnosis of a perceptual disorder after stroke, which was not the focus nor criteria of prior reviews, resulting in limited overlap of included studies and comparability of findings. A further review of 10 studies (*n* = 122) on interventions for Pusher syndrome, classified interventions as robot-assisted gait training, visual feedback, galvanic vestibular stimulation and physiotherapy interventions.[261] They noted early evidence of intervention effectiveness but urged caution in the interpretation due to the small sample sizes and lack of methodological rigor, as also noted in this work. All touch and somatosensation reviews that we identified make similar recommendations for more research in this field.

Additional systematic reviews of interventions for hearing,[77,263] taste and smell[11] perceptual disorders following a stroke are lacking with most reviews identified providing a high-level summary of the diagnostic challenges and the impact of perceptual disorders, mirroring the evidence gaps that we identified in our Cochrane Review.

Previous research prioritisation activities

We identified stroke-related perceptual disorders research priorities. The James Lind Alliance, working at a national level with priority setting partnerships of clinicians, patients and carers to 'identify and prioritise evidence uncertainties', has identified research priorities in topics relevant to the scope of this work. In 2011 the first stroke-related JLA PSP top 10 identified 'What are the best ways to improve cognition after stroke?' as the top priority, with its definition of cognition including perception; in addition, treatments for visual problems were priority number five.[264] The more recent JLA stroke priority setting work (2021) did not include visual or other perceptual-related disorders, though research relating to the prevalence of long-term impacts and associated interventions (#6), support for carers (#8) and what are stroke survivors' experiences of care (#10) were prioritised. A recent Swedish study[265] ranked 'cognition and memory function' as priority 6, with visual problems as number 8. The World Stroke Organization recommendations are not specific to any one post-stroke disorder and rank the need to 'standardize … poststroke rehabilitation based on best evidence' as third most important, behind better acute treatment and stroke prevention.[266]

There are priority setting activities relating to individual senses:

Vision: A research priority setting activity relating to sight loss and vision presented 12 main research priorities but again, none related to perception, though one neuro-ophthalmology-specific subset[93] noted two stroke-related priorities: What rehabilitation or treatment methods are most effective? (#4)' and 'What is the most effective way to assess vision in patients with neurological visual impairment?'(#5).

Hearing: One JLA Top 10 relates mild-to-moderate hearing loss, but appears to focus on sensory loss, not perceptual impairments.[267]

Taste and smell: A priority setting exercise is underway, but has not yet completed its findings.[268]

While there are areas of overlap, our research prioritisation process is not fully represented by existing findings.

Stakeholder input and relevance

It is important to consider to what extent the identified research was pragmatic in nature,[269] reflecting the 'real-world' experiences of stroke survivors, carers and families, and the delivery of care by HCPs.

No included studies reported the involvement of stakeholders (stroke survivor or clinical) in intervention development or study design. Other points where a lack of coherence between the research studies and real world were:

1. Setting: Most studies were conducted in hospitals, whereas most rehabilitation is now provided after discharge, in a community setting.
2. Flexibility (delivery): There was a predominance of one-to-one delivery, requiring input from a clinician throughout; such methods are potentially less feasible in a community setting, and in the context of increasing self-delivery models for stroke care.
3. Organisation: Several interventions, such as robotics or vibrating gloves, were novel and of questionable relevance to current practice. Clinicians suggested that simpler or more frequently used interventions were not adequately examined within the research.
4. Flexibility: The absence of research into intervention implementation, including feasibility, and economic outcomes.
5. Primary analysis: Research was wholly quantitative in nature, with no data gathered on stroke survivors or clinicians' experiences or the acceptability of interventions.
6. Primary outcome: The most frequently reported outcome measures were those of perceptual function. The outcomes of greatest importance to stroke survivors, measures that reflected transfer of training effects to everyday life (e.g. ADLs, EADLs, social activities and participation, psychological well-being and mental health, QoL) were not gathered alongside those of perceptual function.
7. Follow-up: There was also limited assessment of outcomes beyond the end of intervention delivery, with which the longevity of effects could be explored. Similar concerns are seen in other areas of stroke rehabilitation research, reflecting wider challenges in this area of rehabilitation.[6] There is a set of core outcomes and measures for visual disorders in stroke created with stroke survivor representatives;[270] while it focuses on sensory and ocular motor disorders, the guidance on functional visual assessment is useful in this field also.

Potentially some of the limitations in study relevance could have been identified and addressed with greater stakeholder involvement. The benefits of stakeholder involvement are well recognised[271] specifically in enhancing the relevance, implementation and impact of research.

This project involved stakeholder involvement throughout (see *Chapters 3* and *8*). The Clinical Expert Group and Lived Experience Group impacted on the project design (*Chapter 9*), specifically the definition of perception, delineation of disorders, deciding the outcome measures and organising the data syntheses (see *Chapters 5* and *7*). They have contributed to interpreting the results, implications and recommendations for clinicians, stroke survivors, policy-makers.

Equality, diversity and inclusion

Equality, diversity and inclusion in the context of this study

Key factors known to be associated with underrepresentation in stroke research (especially trials) include female sex,[272] ethnic minority background, age (> 80, < 18)[273] and having stroke-related impairments in cognition[274] and language.[275] In our reviews we sought to extract (and categorise) data on age, sex and concurrent impairments to both describe the population and identify areas of limited inclusion. Age and sex data were generally well described (see *Participants included*). We grouped age data into < 18, 18–65 and > 65 years old; 31.3% (25/80) studies had participants aged > 65 years suggested good representation of older stroke survivors; however, as this was not specific to those aged > 80 we cannot comment on any lack of representation in this group. We noted a lack of studies relating to children and under-representation of women. We did not collect data on race/ethnic background; on consideration this may have been a lost opportunity to explore this important issue.

We also collected data on whether studies reported any involvement of stroke survivors or carers in the design and conduct of their study (PPI): no studies reporting any PPI (see *Stroke survivor or family involvement in research*), possibly suggesting of a lack of consideration of stroke survivor's experiences and priorities within perception interventions research.

Accessibility and Inclusivity when presenting results

We were aware of potential barriers to access arising from the complexity and unfamiliarity of perception and perceptual impairment language. We simplified wording in documents, provided glossaries of research and topic-specific terms and provided reminders of the meaning of key terms each time we met. Members of the Lived Experience Group helped to create a lay definition of perception that would be widely understood, and reviewed and edited all Plain Language Summaries for project publications, alongside input from a speech and language therapist research team member familiar with creating accessible versions of research information, to support accessibility. As some members of the Lived Experience Group had visual problems, we used clear print guidance throughout to guide the choice of font layout, use of colour and contrast, etc.

Research team

Our multidisciplinary research team reflected a range of topic and research methodology expertise to support the conduct of the study to a high standard (see *Equality, diversity and inclusion in the context of this study*).

Our involvement of stroke survivors, carers and clinicians was extensive, and is discussed in *Stakeholder input and relevance*.

Strengths

Positionality

The core research team included multidisciplinary researchers with clinical expertise in optometry, audiology, physiotherapy and speech and language therapy, and neuropsychology (adult and paediatric) many of whom are stroke rehabilitation specialists and clinical academics in stroke care. All but one (SH) were based in Scotland. The core group's methodological expertise includes extensive systematic

review and data synthesis methodologies (Cochrane, mixed methods, network meta-analyses), complex interventions, priority setting, reducing research waste and maximising collaborative research efforts to the benefit of people after stroke. The core research team worked closely with the Lived Experience and Clinical Expert Groups [see *Stakeholder activities (what happened)*] who contributed their expertise from the broader perspectives of England (four members), international (one member) and clinical areas of audiology, ENT and visual neuropsychology.

Methodological rigour

We worked to the highest methodological standards. We built upon existing definitions to develop a clear, specific, working definition of perception at project outset and agreed our inclusion criteria in relation to the senses and specific disorders: given the complexity of this topic, this gave clear scope and practical guidance for succeeding activities. The WHO ICF[8] definition underpinned our working definitions and was applied to all senses. This helped us address the challenge of perceptual terminology and reporting, with inconsistent terminology for similar conditions within and between senses, participant populations and disciplinary fields as well as lack of clarity on the precise nature of disorders. Our definition also informed our broad search strategy to identify published and non-published research, from both key electronic databases and a range of other sources including the grey literature. While we recognise that others may develop alternative approaches, our definitions and framework were feasible and were consistently applied across our reviews and supported the reporting of our findings. Thus, these definitions offer a transparent and replicable approach to support future perceptual disorder rehabilitation research.

We reported to the best practice and methodological and reporting guidelines wherever possible including TiDIER,[97] Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA),[128] PRISMA-A, PRISMA-ScR,[117] GRIPP 2,[108] Cochrane Review quality appraisal process for both studies (risk of bias)[223] and comparisons (GRADE),[226,227] ROBIS,[253] and Cochrane methodological guidance for data synthesis.[222]

As noted, prior research has often explored perception in conjunction with sensory, cognitive or attentional deficits. Our very clear focus on perceptual disorders alone is therefore unique. It has offered the opportunity to closely examine the research on this specific set of disorders, and we hope this provides a distinctive contribution to clinical care, enabling HCPs to better focus on and address perception-specific disorders.

Stakeholder involvement

We involved stakeholders from project inception and throughout the study (see *Chapter 3*), using current UK guidance and an established framework to plan and describe involvement.[103]

We acknowledge that our stakeholder discussions were typically based on a small number of participants and somewhat subjective, meaning that discussions (and rankings) could have been biased by the experiences of participants and thus not reflective of a national or international viewpoint. Our involvement of stakeholders in the clinical and research implication sections brings substantial strength, reflecting the views of many people with lived experience of perceptual problems, and of HCPs addressing their care.

Limitations

Lack of evidence

Stroke is the third leading cause of disability worldwide, and a growing number of stroke survivors are living with long-term disabilities, including perceptual disorders. The limited research activity relating to perceptual disorder interventions is important, as is the limited quality of the research identified (see *Chapter 7*). Consequently, there is a significant absence of high-quality evidence informing the provision of stroke care.

The reason for the lack of research in this area is not clear. The Lived Experience Group described how the considerable impact of their perceptual disorders was, for some, only appreciated months after their return home, when access to stroke rehabilitation was limited. An alternative interpretation may be that insight into such disorders may only emerge as other rehabilitation gains are made. Clinical experts suggested that people with severe stroke may have perceptual impairments masked by other conditions such as poor cognition or aphasia which in turn preclude formal assessments and limit self-report. Thus, clinicians may be unaware that a perceptual disorder is present, and why few research studies address the topic. Timely assessment, information provision and treatment should be important.

Our scoping review employed a broad and rigorous search of electronic databases and grey literature, adopting a comprehensive definition of perceptual disorders. Despite these efforts, due to the complex nature of the topic and terminology, some relevant papers may have been missed. In the absence of a universally accepted intervention categorisation, we utilised an existing method to support categorisation consistency, relevant to perceptual disorder research.[125] but which may not necessarily directly align with other categorisation approaches.[276] As a scoping review, we did not conduct quality appraisal and thus comment on quality or generalisability of study findings was not possible. Similarly, we failed to identify qualitative studies that focused on perceptual disorders after stroke; we recognise that some relevant data may have been available in more generic reports of stroke impact reports which may not have been identified in our comprehensive search of the literature. We are aware of one potentially relevant qualitative report published after our scoping review was completed,[277] and of ongoing qualitative work in this field.[278]

Study methodology

The scoping review identified a predominance of single subject and RCT designs, the former describing highly personalised treatments, making clinical relevance and validity difficult to establish. While RCTs can be a high-quality design approach, we found risk of bias concern in most RCTs included in our review. Small RCTs are typically insufficiently powered to generate confidence in conclusions and overlap in the small trials we identified was rare. A co-ordinated and systematic approach to enquiry in this research field is required and our scoping and Cochrane systematic review offer an important foundation on which to build this evidence base.

Reporting limitations

The TiDIER checklist,[97] available since 2014, aims to support the replication of treatment, as reporting gaps have clear consequences for intervention implementation. We sought to extract the relevant intervention data using the TiDIER checklist, where possible describing the rationale, materials, procedures, intervention provider, mode of delivery, location, dosage and any modification of the intervention. Such details were not commonly available (see *Interventions*). Forty per cent (34/80) of the perceptual disorder intervention studies included in our scoping review were published after 2014 and thus intervention reporting could have benefited from use of this checklist.

Representation of senses

Evidence to inform interventions for some senses was lacking; interventions for hearing, taste and smell perceptual disorders and descriptions of their impact on life after stroke were not commonly reported.[28,43–45] Training and guidelines on this topic are limited[3]; however, recent care pathway guidance[279,280] on the assessment and management of visual disorders after stroke gives greater impetus to improving care and the research needed to underpin this.

Paediatric populations

The paediatric population are particularly under-researched in relation to stroke-related perceptual disorders (see *Visual perception disorder interventions*), which reflects the generally limited paediatric stroke rehabilitation evidence base.[281] The paediatric and adult stroke populations are different. We lack agreement about the nature and extent[282] of natural recovery following stroke among the paediatric population (due to neurodevelopmental plasticity);[283] and where extensive recovery is expected, the

need for management interventions is reduced. Greater evidence on the persistence of perceptual disorders and factors affected with this is a key area to inform further research for a paediatric population. Similarly, interventions designed for adult populations may not engage or suit paediatric populations leading to adherence challenges. Thus, paediatric perceptual disorder studies should be developed and conducted to inform their care and rehabilitation.

Impact of the COVID-19 pandemic

Conducted between January 2020 and December 2021, the project was subject to the impacts of the COVID-19 pandemic and associated work-related restrictions. We experienced delays in the literature identification and retrieval of full texts due to the temporary closure of the British Library. Our core research group had prior experience of videoconferencing and pivoted to this format with relative ease, but this was not the case for our Lived Experience Group. Shifting to online methods changed the nature of our meetings and altered communication quality and contribution. Members described difficulties in finding their place in the group, taking in the information presented, speaking naturally and using the technology. Clinical colleagues simultaneously experienced significant clinical demands on their time (such as emergency planning, redeployment, training requirements and supporting their teams or professional bodies with information provision and synthesis). Academic colleagues shifted to home-based working, online teaching and caring activities. As the project and pandemic progressed, demands altered and we are grateful for our clinical, academic and research colleagues' continued contribution and our funder's support over a very challenging period of time.

Clinical implications

Working with our Lived Experience Group and Clinical Expert Group we agreed the implications for stroke survivors, clinicians and policy-makers (see *Chapter 8*, *Implications for stroke survivors and carers*, *Implications for clinicians*, and *Implications for policy-makers*). Overall, the coproduced clinical implications recommend a greater awareness of, assessment for, and information provision relating to stroke-related perceptual disorders, and recommended a holistic approach to intervention and support.

While the evidence was insufficient to support intervention decisions, the scoping review provides a source of information with evidence maps supporting the accessibility of the results, and primary research links if required. The overall Cochrane Review finding indicated that there was insufficient evidence to support any intervention benefits impaired perception after stroke. However, a lack of evidence is not evidence of a lack of effectiveness and the limited studies identified may inform relevant best practice statements and stimulate research in this topic area.

Research implications

Across both reviews, we highlighted the small number of studies (in some cases with methodological limitations) evaluating interventions for perceptual disorders after stroke. Together with our Lived Experience and Clinical Expert Groups we developed the research priorities relating to perceptual disorders in stroke. Future research should develop a better understanding of the experiences of stroke survivors with perceptual problems, their assessment, treatment and current services. Undertaking this work, it will also be essential to establish with greater clarity the incidence, prevalence and natural history of perceptual problems due to stroke, including where this occurs alongside other stroke-related impairments.

Under-researched populations

Most of the research identified in the scoping review related to adults and thus there is a need to address perceptual disorders experienced by children and young people. Similarly, further research on hearing, taste and smell perception disorders is required, particularly to establish the incidence, natural history, prevalence and impact of these.

In developing this research field, guidance on the development of stroke rehabilitation interventions and trials of their effectiveness are available to support the exploration of the mechanisms of action, and questions relating to dosage and target population,[276,284]. In addition, full consideration should be given to the context of care, and feasibility, sustainability and economic factors affecting intervention delivery; pragmatic designs should be considered in order to maximise the clinical relevance and applicability of emerging findings.

Involving stakeholders' priorities

It is important that future research considers the needs of key stakeholders: stroke survivors, carers and families affected by perceptual disorders, and clinicians providing care. Researchers should aim to use a structured process to identify and engage stakeholders as fully as possible, ensuring that their priorities are considered and outcomes of importance addressed with interventions reflecting current practice in community-based settings.

Clarity and completeness of reporting

We suggest that researchers use relevant international reporting standards[97,108,128] for populations, interventions and specific study designs, etc. and fully report key aspects of their research including

- Sufficiently detailed theoretical rationale for, and description of, the interventions to allow implementation into clinical practice and research replication.
- Detailed diagnostic information on individuals' perceptual problems, given the heterogeneity in perceptual problems in terms of type, severity and likely impact on everyday function.
- Recording whether participants have concurrent impairments, including more than one perceptual impairment and/or other stroke and non-stroke relating impairments.

We further suggest the development of standardised terminology for perceptual disorders, to aid clarity or reporting and understanding for researchers, clinicians and stroke survivors, across all the senses. This could further help improve awareness, multidisciplinary identification and intervention for those affected.

Recommendations relating to randomised controlled trial design

Additional recommendations arising from the Cochrane Review and relating specifically to RCTs are:

1. Provide a standard care control group, carefully documenting the content and amount of standard care, which can be highly variable.
2. Endeavour to reduce risk of bias through rigorous methodology and reporting, for example ensure allocation concealment, attempt and report masking of outcome assessors, report all loss to follow-up and results from all outcome measures, control for other biases.
3. Have the statistical power to answer clinically important questions about long-term functional outcomes.
4. Include relevant outcomes, including economic analysis.
5. Adopt an intention-to-treat approach to measurement of outcomes in all individuals as well as to analysis of measured outcomes by treatment group.
6. Investigate real-world interventions, rather than solely novel technologies.

Conclusion

Healthcare professionals lack sufficient evidence to inform clinical interventions for visual, somatosensation, touch, hearing, smell and taste perception disorders after stroke. The available evidence shows limited evidence of rigorous development and testing of interventions, and a preponderance of case report, and small-scale RCTs. We encourage the use of intervention development and reporting guidance, and the involvement of stakeholders to maximise the rigor, relevance and validity of future studies. Our priorities for future research include exploring the prevalence and impact of perceptual disorders, improving assessment, and intervention research, that reflects the reality of current care contexts and population variation.

Additional information

Contributions of authors

Christine Hazelton (https://orcid.org/0000-0002-9554-4750) (Research Fellow, Optometrist, Stroke Rehabilitation) was a principal investigator and led the conceptualisation of the application, methodological design as well as data curation, formal analysis, project administration, supervision, creation of resources and visualisation, validation of results, writing original drafts and reviewing and editing the report. She co-led the acquisition of funding.

Alex Todhunter-Brown (https://orcid.org/0000-0003-4941-7985) (Senior Research Fellow, Systematic Review Specialist) was involved in the conceptualisation of the application, methodological design and funding acquisition as well as conducting the investigation through stakeholder engagement, formal analysis, supervision, creation of resources and visualisation, validation of results, writing original drafts and reviewing and editing the report.

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Kris McGill (https://orcid.org/0000-0002-0307-1440) (Research Associate, Stroke Rehabilitation) conducted the investigation through literature screening and data extraction (including data curation), verified results and edited the report.

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Data-sharing statement

The data can be obtained from the corresponding author upon request.

Ethics statement

This project involved secondary research with stakeholder involvement. No ethical approval is required for secondary research. We sought ethical approval for the stakeholder involvement activities as this is good practice where participants' data are recorded and used. The was approved by Glasgow Caledonian University's School of Health and Life Sciences Nursing Department Research Ethics Committee (HLS/NCH/19/021) on 16 January 2020.

Information governance statement

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Disclosure of interests

Full disclosure of interests: Completed ICMJE forms for all authors, including all related interests, are available in the toolkit on the NIHR Journals Library report publication page at https://doi.org/10.3310/WGJT3471.

Primary conflicts of interest: Christine Hazelton has declared personal funding from the Stroke Association, UK via a non-clinical Lectureship (SA L-NC 20\100003) and grant funding from NIHR Research for Patient Benefit programme (PB-PG-0418-20040), and Fight for Sight/Stroke Association. Alex Todhunter-Brown is (joint) co-ordinating editor for Cochrane Stroke. Funding to support this role is provided by the Scottish Government's Chief Scientist Office. Pauline Campbell has declared funding from NIHR (NIHR128829; NIHR128470; NIHR132895) and Chief Scientist Office (Scotland; HIPS/21/03). Katie Thomson has declared an honorarium and travel expenses for the Occupational Therapy Show, consultancy fees from NHS Fife and a Global Challenges Networking Grant. Donald J Nicolson has declared being employed for an SME Medical Device Company (Metix Medical) for 2 years (May 2019–July 2021) as the Medical Science Liaison, winning an Innovate UK award for the Business-led innovation in response to global disruption (de minimis) funding application stream. This evaluated the utility of a prototype high-acuity monitoring device. He was the grant holder and project lead and drew a salary from this project. He is also an employee of Healthcare Improvement. Scotland since July 2021 and is attached to the SIGN team. In 2018 he received travel expenses to present at the Association for Borderlands Studies World Conference. Charlie Chung has declared membership of the Cochrane Stroke Group and funding from the Chief Scientist Office (Scotland). Marian C Brady has declared grant funding from the Chief Scientist Office, NIHR Research for Patient Benefit programme (NIHR200739) and the Health and Social Care Delivery Research (NIHR132895) programme, the Tavistock Trust for Aphasia, NHS Greater Glasgow and Clyde Endowment Fund, Academy of Medical Sciences and the British Aphasiology Society. She has also declared travel and accommodation support from the New Zealand Speech and Language Therapist's Association to attend the Speech Pathology Australia National Conference. She is also a member of the Data Monitoring Committee for the NIHR PhEAST trial (NIHR132016), and is chair of the Virtual International Stroke Trials Archive-Rehabilitation as well as the Collaboration of Aphasia Trialists and the International Association of Communication Science and Disorders. She is a committee member of the Aphasia Alliance (UK) and the UK Aphasia Advisory Committee. She is an editorial board member (associate editor) of both the Cochrane Stroke Editorial Group and Aphasiology and board member of the International Association of Communication Sciences and Disorders. All other authors have declared no competing interests.

Publications

Hazelton C, McGill K, Campbell P, Todhunter-Brown A, Thomson K, Nicolson DJ, *et al.* Perceptual disorders after stroke: a scoping review of interventions. *Stroke* 2022;**53**:1772–87. https://doi.org/10.1161/STROKEAHA.121.035671

Hazelton C, Thomson K, Todhunter-Brown A, Campbell P, Chung CS, Dorris L, *et al.* Interventions for perceptual disorders following stroke. *Cochrane Database Syst Rev* 2022;**11**:CD007039. https://doi.org/10.1002/14651858.CD007039.pub3

Hazelton C, Campbell P, Chung C, Dorris L, Gillespie D, Hunter D, et al. Perceptual disorders after stroke InterventiON EvidencE Review (PIONEER): a scoping review and Cochrane Review revision and expansion. Study Protocol (version 1.1). *NIHR Health Technology Journals* 2021:1–34.

Conference presentations

Hazelton C, McGill K, Pollock A, Campbell P, Chung C, *et al. Interventions for Visual Perceptual Disorder after Stroke: A Scoping Review*. Oral Presentation – Dutch Congress of Rehabilitation Medicine, 2020.

Hazelton C, McGill K, Pollock A, Campbell P, Thomson K, *et al.Interventions for Perceptual Disorders Following Stroke*. Oral Presentation – Occupational Therapy Show, 2021.

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Hazelton C, McGill K, Pollock A, Campbell P, Thomson K, *et al. Perceptual Disorders after Stroke: A Scoping Review of Interventions with Evidence Gap Mapping*. Oral Presentation – Ageing Well with Stroke Conference, 2021.

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Hazelton C, Thomson K, McGill K, Pollock A, Campbell P, Chung C, *et al. Interventions for Perceptual Disorders after Stroke: What is the Research to Date?* Oral Presentation – UK Stroke Forum, 2021.

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Appendix 1 Search terms – MEDLINE search strategy

Search methods and strategies for this review were written by the Cochrane Stroke Group's Information Specialist (JDC). The 'Search methods for identification of studies' and corresponding search strategies reported here are written based on the review's research question, inclusion criteria in close consultation with the review team drawing on the Information Specialist's subject expertise. The following search hedge/filter is often used as a basis for constructing search strategies and is adapted where necessary.

The search strategies were adapted from the following reference.[285]

1. cerebrovascular disorders/ or basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp cerebral small vessel diseases/ or exp intracranial arterial diseases/ or exp 'intracranial embolism and thrombosis'/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or stroke, lacunar/ or vasospasm, intracranial/ or vertebral artery dissection/ or carotid stenosis/ or exp carotid artery injuries/ or intracranial arterial diseases/ or cerebral arterial diseases/ or infarction, anterior cerebral artery/ or infarction, middle cerebral artery/ or infarction, posterior cerebral artery/ or exp carotid arteries/ or endarterectomy, carotid/
2. (stroke$ or poststroke or apoplex$ or cerebral vasc$ or brain vasc$ or cerebrovasc$ or cva$ or SAH).ti,ab
3. ((brain$ or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebral arter$ or MCA$ or anterior circulation or posterior circulation or basilar arter$ or vertebral arter$ or space-occupying) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).ti,ab
4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracran$ or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli$ or putaminal or putamen or posterior fossa or hemispher$ or subarachnoid) adj5 (h?emorrhag$ or h?ematoma$ or bleed$)).ti,ab
5. or/1-4
6. exp perceptual disorders/ or exp perception/
7. hearing disorders/ or hearing loss/ or deafness/ or hearing loss, central/ or hearing loss, sudden/ or hyperacusis/ or olfaction disorders/ or exp somatosensory disorders/ or exp taste disorders/ or vision disorders/ or alice in wonderland syndrome/ or amblyopia/ or blindness/ or blindness, cortical/ or color vision defects/ or diplopia/ or hemianopsia/ or photophobia/ or scotoma/ or vision, low/
8. (percept$ adj3 (impair$ or problem$ or abilit$ or deficit$ or distortion$ or defect$ or disabilit$ or disturbance$ or disorder$ or discriminat$ or deaf$)).ti,ab
9. (agnosis or agnosia or prosopagnosia or prosophthalmia or Alice in Wonderland syndrome or Todd syndrome or all?esthesia$ or syn?esthesia$ or hypoesthesia or hyperesthesia).ti,ab
10. sensation/ or hearing/ or smell/ or taste/ or touch/ or vision, ocular/ or color vision/ or exp mesopic vision/ or night vision/
11. (somatosensory$ or (sensor$ adj3 (input$ or stimul$ or deficit$ or distortion$ or defect$ or disabilit$ or disturbance$ or disorder$ or discriminat$ or processing or percept$ or hallucination$ or feedback or discriminat$ or dysfunction$ or recogn$ or interpretation)) or somatosognosia or asomatognosia or somatoparaphrenia or (body adj3 (schema or orientation))).ti,ab
12. exp Proprioception/
13. (propriocep$ or (kin?esthetic adj3 (percept$ or discriminat$))).ti,ab
14. ((odo?r$ or smell$ or olfact$ or scent$ or aroma or flavo?r) adj3 (memory or acuity or function$ or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hedonics or deprivation or hallucinat$)).ti,ab

15. (anosmia or anodmia or anosmy or Kallmann syndrome or dysosmia or hyposmia or hyposphresia or phantosmia or par?osmia or ageusia or hypogeusia or dysgeusia or troposmia or euosmia or cacosmia or malodour or superosmia).ti,ab
16. (ageusia or dysgeusia or parageusia or phantogeusia or hypogeusia or amblygeustia or hypogeusesthesia or hyp?esthesia or superosmia or phantosmia or parosmia or troposmia or euosmia or cacosmia or dysosmia or hypergeusia or phantogeusia or hyperosmia or hyposmia).ti,ab
17. ((gustat$ or tast$) adj3 (acuity or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hallucination$ or abnormalit$ or distortion$ or disturbance$ or anomal$ or loss or an?esthesia or absence or phantom)).ti,ab
18. (((speech or speak$ or voice or spoken or acoustic or audio or auditory or sound or pitch or prosody or binaural or phoneme) adj3 (percept$ or processing or stimul$ or distinguish$ or discriminat$)) or hyperacusis or misophonia or phonophobia or sonophobia or amusia or King Kopetsky syndrome).ti,ab
19. (amblyop? or aniseikonia or oscillopsia or xanthopsia or d?plop$ or polyop$ or metamorphopsia or m?cropsia or ((vision or visual or visual?percept$ or visuo?spatial or visuo?construct$ or ocular or optokinetic or optic$ or oculomotor spatial) adj3 (illusion or blurry or overload or double or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hallucination$ or abnormalit$ or distortion$ or disturbance$ or anomal$ or disorientation or allachethesia or deficit$ or defect$ or disabilit$ or disorder$ or processing or dysfunction$ or recogn$ or interpretation or analysis or comprehension)) or stereoillusion or kakopsia or kalopsia or pelopsia or archromatopsia or akinetopsia or telopsia or stereopsis or palinopsia or teleopsia or simultanagnosia).ti,ab
20. (entomopia or palinopsia or asteropsis or strabismus or Anton syndrome or Balint syndrome or blindsight or achromatopsia or hyperchromatosis or ((facial or face) adj3 intermetamorphosis) or (visual adj3 anoneria)).ti,ab
21. ((figure or shape or orientation or form or colo?r or textur$ or crowding or contour or object or face or faces) adj3 recogn$).ti,ab
22. (astereognosia or stereognosis or astereognosis or paraesthesia or hypersensitivity or ((tactile or haptic$ or touch) adj3 (stimul$ or memory or acuity or sens$ or percept$ or processing or stimul$ or distinguish$ or discriminat$ or anisotropy or locali?ation))).ti,ab
23. or/6-22
24. 5 and 23

Appendix 2 Studies included in the scoping review

No.	Study ID	Reference
1	An 2019[75]	An C, Roh J, Kim T, Choi H, Choi K, Gyoung-mo Kim. Visual and somatosensory integration processing is needed to reduce pusher behavior (PB) and improve postural control in hemiplegic patients with acute stroke. *Phys Ther Korea* 2019;**26**:57–66.
2	An 2020[162]	An CM, Ko MH, Kim D hyun, Kim GW. Effect of postural training using a whole-body tilt apparatus in subacute stroke patients with lateropulsion: A single-blinded randomized controlled trial. *Ann Phys Rehabil Med* 2020. https://doi.org/10.1016/j.rehab.2020.05.001
3	Babyar 2018[182]	Babyar S, Santos T, Will-Lemos T, Mazin S, Edwards D, Reding M. Sinusoidal transcranial direct current versus galvanic vestibular stimulation for treatment of lateropulsion poststroke. *J Stroke Cerebrovasc Dis* 2018;**27**:3621–5.
4	Bergmann 2018[163]	Bergmann J, Krewer C, Jahn K, Muller F. Robot-assisted gait training to reduce pusher behavior A randomized controlled trial. *Neurology* 2018;**91**:E1319–27.
5	Broetz 2004[164]	Broetz D, Johannsen L, Karnath HO. Time course of 'pusher syndrome' under visual feedback treatment. *Physiother Res Int* 2004;**9**:138–43.
6	Brunsdon 2007[138]	Brunsdon R, Nickels L, Coltheart M, Joy P. Assessment and treatment of childhood topographical disorientation: a case study. *Neuropsychol Rehabil* 2007;**17**:53–94.
7	Burr 1972[143]	Burr M, Hazen B. The use of television in the rehabilitation of stroke patients with perceptual difficulties. *AOTJ* 1972;**Jan–Mar**:19–22.
8	Carey 1993[194]	Carey LM, Matyas TA, Oke LE. Sensory loss in stroke patients: effective training of tactile and proprioceptive discrimination. *Arch Phys Med Rehabil* 1993;**74**:602–11.
9	Carey 2005[195]	Carey LM, Matyas TA. Training of somatosensory discrimination after stroke: facilitation of stimulus generalization. *Am J Phys Med Rehabil* 2005;**84**:428–42.
10	Carey 2011[74]	Carey L, Macdonell R, Matyas TA. SENSe: Study of the effectiveness of neurorehabilitation on sensation: a randomized controlled trial. *Neurorehabil Neural Repair* 2011;**25**:304–13.
11	Carey 2016[198]	Carey LM, Abbott DF, Lamp G, Puce A, Seitz RJ, Donnan GA. Same intervention-different reorganization: the impact of lesion location on training-facilitated somatosensory recovery after stroke. *Neurorehabil Neural Repair* 2016;**30**:988–1000.
12	Chen 2011[130]	Chen CC, Liu HC. Low-dose aripiprazole resolved complex hallucinations in the left visual field after right occipital infarction (Charles Bonnet syndrome). *Psychogeriatrics* 2011;**11**:116–8.
13	Chen 2012[154]	Chen P, Hartman AJ, Priscilla Galarza C, DeLuca J. Global processing training to improve visuospatial memory deficits after right-brain stroke. *Arch Clin Neuropsychol* 2012;**27**:891–905.
14	Cho 2015[66]	Cho HY, Kim K, Lee B, Jung J. The effect of neurofeedback on a brain wave and visual perception in stroke: a randomized control trial. *J Phys Ther Sci* 2015;**27**:673–6.
15	Choi 2018[144]	Choi D, Choi W, Lee S. Influence of Nintendo Wii Fit balance game on visual perception, postural balance, and walking in stroke survivors: a pilot randomized clinical trial. *Games Health J* 2018;**7**:377–84.

No.	Study ID	Reference
16	Cogan 1973[134]	Cogan DG. Visual hallucinations as release phenomena. *Albr von Graefes Arch für Klin und Exp Ophthalmol* 1973;**188**:139–50.
17	Colombo 2016[185]	Colombo R, Sterpi I, Mazzone A, Delconte C, Pisano F. Improving proprioceptive deficits after stroke through robot-assisted training of the upper limb: a pilot case report study. *Neurocase* 2016;**22**:191–200.
18	Dutton 2017[145]	Dutton GN, Chokron S, Little S, McDowell N. Posterior parietal visual dysfunction: an explanatory review. *Vis Dev Rehabil* 2017;**3**:10–22.
19	Edmans 1991[146]	Edmans JA, Lincoln NB. Treatment of visual perceptual deficits after stroke: single case studies on four patients with right hemiplegia. *Br J Occup Ther* 1991;**54**:139–44.
20	Edmans 2000[60]	Edmans JA, Webster J, Lincoln NB. A comparison of two approaches in the treatment of perceptual problems after stroke. *Clin Rehabil* 2000 [cited 2019 May 11];**14**:230–43.
21	Enders 2013[199]	Enders LR, Hur P, Johnson MJ, Seo NJ. Remote vibrotactile noise improves light touch sensation in stroke survivors' fingertips via stochastic resonance. *J Neuroeng Rehabil* 2013;**10**:1–8.
22	Fechtelpeter 1990[193]	Fechtelpeter A, Goddenhenrich S, Huber W, Springer L. Ansatze Therapie von auditiver Agnosie. *Folia Phoniatr* 1990;**42**:83–97.
23	Fifer 1993[188]	Fifer RC. Insular stroke causing unilateral auditory processing disorder: case report. *J Am Acad Audiol* 1993;**4**:364–369
24	Flint 2005[135]	Flint AC, Loh JP, Brust JCM. Vivid visual hallucinations from occipital lobe infarction. *Neurology*. 2005;**65**:754–756
25	Freitas 2017[165]	Freitas ACM, Bezerra LAP, Oliveira PCA de, Freitas LM, Silva SR da, Cirne GN de M, Cacho R de O. Evaluation of the effectiveness of mirror therapy in Pusher syndrome and hemineglect in post-stroke patients. *Fisioter Bras* 2017;**18**:362–8.
26	Fujimoto 2016[200]	Fujimoto S, Kon N, Otaka Y, Yamaguchi T, Nakayama T, Kondo K, Ragert P, Tanaka S. Transcranial direct current stimulation over the primary and secondary somatosensory cortices transiently improves tactile spatial discrimination in stroke patients. *Front Neurosci* 2016;**10**:1–9.
27	Fujino 2016[166]	Fujino Y, Amimoto K, Sugimoto S, Fukata K, Inoue M, Takahashi H, Makita S. Prone positioning reduces severe pushing behavior: three case studies. *J Phys Ther Sci* 2016;**28**:2690–2693.
28	Fujino 2019[167]	Fujino Y, Takahashi H, Fukata K, Inoue M, Shida K, Matsuda T, Makita S, Amimoto K. Electromyography-guided electrical stimulation therapy for patients with pusher behavior: a case series. *NeuroRehabilitation* 2019;**45**:537–45.
29	Funk 2013[155]	Funk J, Finke K, Reinhart S, Kardinal M, Utz KS, Rosenthal A, Kuhn C, Müller H, Kerkhoff G. Effects of feedback-based visual line-orientation discrimination training for visuospatial disorders after stroke. *Neurorehabil Neural Repair* 2013;**27**:142–52.
30	Gillen 2003[158]	Gillen JA, Dutton GN. Balint's syndrome in a 10-year-old male: a case report. *Dev Med Child Neurol* 2003;**45**:349–52.
31	Gillespie 2019[168]	Gillespie J, Callender L, Driver S. Usefulness of a standing frame to improve contraversive pushing in a patient post-stroke in inpatient rehabilitation. *Baylor Univ Med Cent Proc* 2019;**32**:440–2.
32	Gottlieb 1991[142]	Gottlieb D, Calvanio R, Levine D. Reappearance of the visual percept after intentional blinking in a patient with Balint's syndrome. *J Clin Neuroophthalmol* 1991;**11**:62–5.
33	Hayashi 2004[196]	Hayashi R. Olfactory illusions and hallucinations after right temporal hemorrhage. *Eur Neurol* 2004;**51**:240–1.

No.	Study ID	Reference
34	Jahn 2017[169]	Jahn K, Müller F, Koenig E, Krewer C, Tillmann S, Bergmann J. Rehabilitation of verticality perception using a new training method. *J Neurol* 2017;**264**:26–7.
35	Jamal 2017[186]	Jamal K, Leplaideur S, Rousseau C, Chochina L, Moulinet-Raillon A, Senal N, Bonan I. The long-lasting effects of repetitive neck muscle vibration on postural disturbances in standing position in chronic patients. *Neurophysiol Clin* 2017;**47**:341–2.
36	Jang 2018[170]	Jang SH, Lee H Do. Recovery of an injured medial lemniscus with concurrent recovery of pusher syndrome in a stroke patient: a case report. *Med* 2018;**97**:21–3.
37	Jo 2012 [286]	Jo K, Yu J, Jung J. Effects of virtual reality-based rehabilitation on upper extremity function and visual perception in stroke patients: a randomized control trial. *J Phys Ther Sci* 2012;**24**:1205–8.
38	Jokelainen 2000[171]	Jokelainen L, Jokelainen M. Työntöoireyhtymä. *Duodecim* 2000;**116**:144–7.
39	Kang 2009[147]	Kang SH, Kim DK, Seo KM, Choi KN, Yoo JY, Sung SY, Park HJ. A computerized visual perception rehabilitation programme with interactive computer interface using motion tracking technology – a randomized controlled, single-blinded, pilot clinical trial study. *Clin Rehabil* 2009;**23**:434–44.
40	Kim 2011[148]	Kim EJ, Lee KE, Lee KL, Kim HG, Yoon Y, Jeon SY, Yu JA. Change of visual perception in geriatric strokes after visuomotor coordination training. *Ann Rehabil Med* 2011;**35**:174–9.
41	Kim 2015[201]	Kim B, Bang D, Shin W. Effects of pressure sense perception training on unstable surface on somatosensory, balance and gait function in patients with stroke. *J Korean Soc Phys Med* 2015;**10**:19–27.
42	Kim 2016[172]	Kim MS. Effect of robot assisted rehabilitation based on visual feedback in post stroke Pusher syndrome. *J Korea Acad Coop Soc* 2016;**17**:562–8.
43	Kitisomprayoonkul 2012[202]	Kitisomprayoonkul W. Transcranial direct current stimulation improves hand sensation in acute stroke. *Arch Phys Med Rehabil* 2012;**93**:e33.
44	Ko 2018[161]	Ko EJ, Chun MH, Kim DY, Kang Y, Lee SJ, Yi JH, Chang MC, Lee SY. Frenkel's exercise on lower limb sensation and balance in subacute ischemic stroke patients with impaired proprioception. *Neurol Asia* 2018;**23**:217–24.
45	Koo 2018[187]	Koo WR, Jang BH, Kim CR. Effects of anodal transcranial direct current stimulation on somatosensory recovery after stroke. *Am J Phys Med Rehabil* 2018;**97**:507–13.
46	Koohi 2017 (1)[68]	Koohi N, Vickers D, Chandrashekar H, Tsang B, Werring D, Bamiou DE. Auditory rehabilitation after stroke: treatment of auditory processing disorders in stroke patients with personal frequency-modulated (FM) systems. *Disabil Rehabil* 2017;**39**:586–93.
47	Koohi 2017 (2)[189]	Koohi N, Vickers D, Warren J, Werring D, Bamiou DE. Long-term use benefits of personal frequency-modulated systems for speech in noise perception in patients with stroke with auditory processing deficits: a non-randomised controlled trial study. *BMJ Open* 2017;**7**:1–7.
48	Krewer 2013[183]	Krewer C, Rieß K, Bergmann J, Müller F, Jahn K, Koenig E. Immediate effectiveness of single-session therapeutic interventions in pusher behaviour. *Gait Posture* 2013;**37**:246–50.
49	Lee 2017[173]	Lee JT, Chon SC. Does the addition of visual feedback improve postural vertical training in the patients with Pusher syndrome after stroke? *J Korean Soc Phys Med* 2017;**12**:33–42.
50	Lincoln 1985[150]	Lincoln NB, Whiting SE, Cockburn J, Bhavnani G. An evaluation of perceptual retraining. *Disabil Rehabil* 1985;**7**:99–101.

No.	Study ID	Reference
51	McDowell 2019[141]	McDowell N, Dutton GN. Hemianopia and features of Bálint syndrome following occipital lobe hemorrhage: identification and patient understanding have aided functional improvement years after onset. *Case Rep Ophthalmol Med* 2019;1–7.
52	Meneghetti 2009[174]	Meneghetti CHZ, Basqueira C, Fioramonte C, Ferracini Júnior LC. Influence of hydrotherapy on trunk control in the pusher syndrome: case report. *Fisioter e Pesqui* 2009;**16**:269–273.
53	Mikołajewska 2012[175]	Mikołajewska E. Posterior pusher syndrome – case report. *Cent Eur J Med* 2012;**7**:354–7.
54	Morioka 2003[203]	Morioka S, Yagi F. Effects of perceptual learning exercises on standing balance using a hardness discrimination task in hemiplegic patients following stroke: a randomized controlled pilot trial. *Clin Rehabil* 2003;**17**:600–7.
55	Nakagawa 1999[131]	Nakagawa N, Akai F, Niiyyama K, Asai T, Tanada M. A case of peduncular hallucination after aneurysmal subarachnoid hemorrhage. *No To Shinkei* 1999;**51**:65–8.
56	Nakamura 2014[184]	Nakamura J, Kita Y, Yuda T, Ikuno K, Okada Y, Shomoto K. Effects of galvanic vestibular stimulation combined with physical therapy on pusher behavior in stroke patients: a case series. *NeuroRehabilitation* 2014;**35**:31–7.
57	Nguyen 2011[132]	Nguyen H, Le C, Nguyen H. Charles Bonnet syndrome in an elderly patient with acute cerebellar infarction treated successfully with haloperidol. *J Am Geriatr Soc* 2011;**59**:761–2.
58	O'Hare 1998[153]	O'Hare AE, Dutton GN, Green D, Coull R. Evolution of a form of pure alexia without agraphia in a child sustaining occipital lobe infarction at 2 1/4 years. *Dev Med Child Neurol* 1998;**40**:417–20.
59	Oppenlander 2015[197]	Oppenlander K, Utz KS, Reinhart S, Keller I, Kerkhoff G. Subliminal galvanic-vestibular stimulation recalibrates the distorted visual and tactile subjective vertical in right-sided stroke. *Neuropsychologia* 2015;**74**:178–83.
60	Papathanasiou 1998[190]	Papathanasiou I, Macfarlane S, Heron C. A case of verbal auditory agnosia: missing the word … missing the sound… *Int J Lang Commun Disord* 1998;**33**:214–7.
61	Pardo 2019[176]	Pardo V, Galen S. Treatment interventions for pusher syndrome: a case series. *NeuroRehabilitation* 2019;**44**:131–40.
62	Park 2015[152]	Park JH, Park JH. The effects of a Korean computer-based cognitive rehabilitation program on cognitive function and visual perception ability of patients with acute stroke. *J Phys Ther Sci* 2015;**27**:2577–9.
63	Poetter 2008[136]	Poetter CE, Vyas BB, Stewart JT, Haley JA. An unusual case of post-stroke hallucinations *J Am Geriatr Soc* 2008;**56**:181–3.
64	Rafique 2016[137]	Rafique SA, Richards JR, Steeves JKE. rTMS reduces cortical imbalance associated with visual hallucinations after occipital stroke. *Neurology* 2016;**87**:1493–500.
65	Roberts-Woodbury 2016[133]	Roberts-Woodbury. Visual hallucinations after a stroke. *J Am Geriatr Soc* 2016;**64**:s159.
66	Scheets 2007[177]	Scheets PL, Sahrmann SA, Norton BJ. Use of movement system diagnoses in the management of patients with neuromuscular conditions: a multiple-patient case report. *Phys Ther* 2007;**87**:654–69.
67	Tanemura 1999[139]	Tanemura R. Awareness in apraxia and agnosia. *Top Stroke Rehabil* 1999;**6**:33–42.
68	Towle 1990[157]	Towle D, Edmans JA, Lincoln NB. An evaluation of a group treatment programme for stroke patients with perceptual deficits. *Int J Rehabil Res* 1990;**13**:328–335.

No.	Study ID	Reference
69	Voos 2011[178]	Voos MC, Oliveira T de P, Piemonte MEP. Guidelines for assessment and physical therapy treatment in Pusher's syndrome: case report. *Fisioter e Pesqui* 2011;**18**:323–8.
70	Wang 2016[179]	Wang D, Lin J, Liu X. Effects of visual feedback and core stability training program on post-stroke Pusher syndrome: a pilot randomized controlled study. *Chinese J Rehab Med* 2016;**31**:426–9.
71	Weinberg 1982[159]	Weinberg J, Piasetsky E, Diller L, Gordon W. Treating perceptual organization deficits in nonneglecting RBD stroke patients*. *J Clin Neuropsychol* 1982;**4**:59–75.
72	Woolf 2014[191]	Woolf C, Panton A, Rosen S, Best W, Marshall J. Therapy for auditory processing impairment in aphasia: an evaluation of two approaches. *Aphasiology* 2014;**28**:1481–505.
73	Yang 2015[180]	Yang YR, Chen YH, Chang HC, Chan RC, Wei SH, Wang RY. Effects of interactive visual feedback training on post-stroke pusher syndrome: a pilot randomized controlled study. *Clin Rehabil* 2015;**29**:987–93.
74	Yun 2018[181]	Yun N, Joo MC, Kim SC, Kim MS. Robot-assisted gait training effectively improved lateropulsion in subacute stroke patients: a single-blinded randomized controlled trial. *Eur J Phys Rehabil Med* 2018;**54**:827–36.
75	Zaharia-Pushkash 2010[160]	Zaharia-Pushkash O, Oleg P, Rodica V, Andrei U. Posterior cerebral artery stroke with Balint's syndrome and severe cognitive impairment: clinical and neuroimaging correlation. *Int J Stroke* 2010;**5**:365–6.
76	Zgaljardic 2013[192]	Zgaljardic D, Yancy S, Burton V, Masel B. Auditory agnosia and Post-Acute Brain Injury Rehabilitation (PABIR): a case report. *J Head Trauma Rehabil* 2013;**28**:E35–6.
77	Zihl 2000 (1) [151]	Zihl J. Visual agnosia. In *Rehabilitation of Visual Disorders after Brain Injury*. Hove, UK: Psychology Press; 2000. pp. 136–50.
78	Zihl 2000 (2)[156]	Zihl J. Visual agnosia: Balint's syndrome and its treatment. In *Rehabilitation of Visual Disorders after Brain Injury*. Hove: 2000. p. 122–31.
79	Zihl 2000 (3)[149]	Zihl J. Disorders in space perception. In *Rehabilitation of Visual Disorders after Brain Injury*. Hove, UK: Psychology Press; 2000. pp. 110–22.
80	Zihl 2000 (4)[140]	Zihl J. Colour vision deficits. In *Rehabilitation of Visual Disorders after Brain Injury*. Hove: Psychology Press; 2000. pp. 102–6.

Appendix 3 Search terms – MEDLINE search strategy for the Cochrane Review

Search methods and strategies for this review were written by the Cochrane Stroke Group's Information Specialist (JDC). The 'Search methods for identification of studies' and corresponding search strategies reported here are written based on the review's research question, inclusion criteria in close consultation with the review team drawing on the Information Specialist's subject expertise. The following search hedge/filter is often used as a basis for constructing search strategies and is adapted where necessary.

The search strategies were adapted from the following reference.[285]

1. cerebrovascular disorders/ or basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp cerebral small vessel diseases/ or exp intracranial arterial diseases/ or exp 'intracranial embolism and thrombosis'/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or stroke, lacunar/ or vasospasm, intracranial/ or vertebral artery dissection/ or carotid stenosis/ or exp carotid artery injuries/ or intracranial arterial diseases/ or cerebral arterial diseases/ or infarction, anterior cerebral artery/ or infarction, middle cerebral artery/ or infarction, posterior cerebral artery/ or exp carotid arteries/ or endarterectomy, carotid/
2. (stroke$ or poststroke or apoplex$ or cerebral vasc$ or brain vasc$ or cerebrovasc$ or cva$ or SAH).ti,ab.
3. ((brain$ or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebral arter$ or MCA$ or anterior circulation or posterior circulation or basilar arter$ or vertebral arter$ or space-occupying) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).ti,ab.
4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracran$ or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli$ or putaminal or putamen or posterior fossa or hemispher$ or subarachnoid) adj5 (h?emorrhag$ or h?ematoma$ or bleed$)).ti,ab.
5. or/1-4
6. exp perceptual disorders/ or exp perception/
7. hearing disorders/ or hearing loss/ or deafness/ or hearing loss, central/ or hearing loss, sudden/ or hyperacusis/ or olfaction disorders/ or exp somatosensory disorders/ or exp taste disorders/ or vision disorders/ or alice in wonderland syndrome/ or amblyopia/ or blindness/ or blindness, cortical/ or color vision defects/ or diplopia/ or hemianopsia/ or photophobia/ or scotoma/ or vision, low/
8. (percept$ adj3 (impair$ or problem$ or abilit$ or deficit$ or distortion$ or defect$ or disabilit$ or disturbance$ or disorder$ or discriminat$ or deaf$)).ti,ab.
9. (agnosis or agnosia or prosopagnosia or prosophthalmia or Alice in Wonderland syndrome or Todd syndrome or all?esthesia$ or syn?esthesia$ or hypoesthesia or hyperesthesia).ti,ab.
10. sensation/ or hearing/ or smell/ or taste/ or touch/ or vision, ocular/ or color vision/ or exp mesopic vision/ or night vision/
11. (somatosensory$ or (sensor$ adj3 (input$ or stimul$ or deficit$ or distortion$ or defect$ or disabilit$ or disturbance$ or disorder$ or discriminat$ or processing or percept$ or hallucination$ or feedback or discriminat$ or dysfunction$ or recogn$ or interpretation)) or somatosognosia or asomatognosia or somatoparaphrenia or (body adj3 (schema or orientation))).ti,ab.
12. exp Proprioception/
13. (propriocep$ or (kin?esthetic adj3 (percept$ or discriminat$))).ti,ab.
14. ((odo?r$ or smell$ or olfact$ or scent$ or aroma or flavo?r) adj3 (memory or acuity or function$ or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hedonics or deprivation or hallucinat$)).ti,ab.

15. (anosmia or anodmia or anosmy or Kallmann syndrome or dysosmia or hyposmia or hyposphresia or phantosmia or par?osmia or ageusia or hypogeusia or dysgeusia or troposmia or euosmia or cacosmia or malodour or superosmia).ti,ab.
16. (ageusia or dysgeusia or parageusia or phantogeusia or hypogeusia or amblygeustia or hypogeusesthesia or hyp?esthesia or superosmia or phantosmia or parosmia or troposmia or euosmia or cacosmia or dysosmia or hypergeusia or phantogeusia or hyperosmia or hyposmia).ti,ab.
17. ((gustat$ or tast$) adj3 (acuity or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hallucination$ or abnormalit$ or distortion$ or disturbance$ or anomal$ or loss or an?esthesia or absence or phantom)).ti,ab.
18. (((speech or speak$ or voice or spoken or acoustic or audio or auditory or sound or pitch or prosody or binaural or phoneme) adj3 (percept$ or processing or stimul$ or distinguish$ or discriminat$)) or hyperacusis or misophonia or phonophobia or sonophobia or amusia or King Kopetsky syndrome).ti,ab.
19. (amblyop? or aniseikonia or oscillopsia or xanthopsia or d?plop$ or polyop$ or metamorphopsia or m?cropsia or ((vision or visual or visual?percept$ or visuo?spatial or visuo?construct$ or ocular or optokinetic or optic$ or oculomotor spatial) adj3 (illusion or blurry or overload or double or percept$ or perceive$ or discriminat$ or distinguish$ or recept$ or sensitiv$ or hallucination$ or abnormalit$ or distortion$ or disturbance$ or anomal$ or disorientation or allachethesia or deficit$ or defect$ or disabilit$ or disorder$ or processing or dysfunction$ or recogn$ or interpretation or analysis or comprehension)) or stereoillusion or kakopsia or kalopsia or pelopsia or archromatopsia or akinetopsia or telopsia or stereopsis or palinopsia or teleopsia or simultanagnosia).ti,ab.
20. (entomopia or palinopsia or asteropsis or strabismus or Anton syndrome or Balint syndrome or blindsight or achromatopsia or hyperchromatosis or ((facial or face) adj3 intermetamorphosis) or (visual adj3 anoneria)).ti,ab.
21. ((figure or shape or orientation or form or colo?r or textur$ or crowding or contour or object or face or faces) adj3 recogn$).ti,ab.
22. (astereognosia or stereognosis or astereognosis or paraesthesia or hypersensitivity or ((tactile or haptic$ or touch) adj3 (stimul$ or memory or acuity or sens$ or percept$ or processing or stimul$ or distinguish$ or discriminat$ or anisotropy or locali?ation))).ti,ab.
23. or/6-22
24. 5 and 23
25. randomized controlled trial.pt.
26. controlled clinical trial.pt.
27. randomized.ab.
28. placebo.ab.
29. clinical trials as topic.sh.
30. random$.ab.
31. trial.ti.
32. or/25-31
33. exp animals/not humans.sh.
34. 32 not 33
35. 34 and 24

Appendix 4 Key details of included randomised controlled trials

An 2019[75]	
Participants	**Sense:** Somatosensation (Pusher syndrome) *n* = 14
Comparison:	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Game-based vertical posture training Rehabilitation (restitution) **Intervention 2:** Standard vertical posture training Rehabilitation (restitution)
Outcome measures	**ADLs:** Korean Modified Barthel Index **Perception:** Burke Lateropulsion Scale **Motor:** Postural Assessment Scale for Stroke, Balance posture ratio **Timing:** Immediately post intervention
An 2020[162]	
Participants	**Sense:** Somatosensation *n* = 30
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Whole-body tilting postural training (*n* = 15) Rehabilitation (restitution) **Intervention 2:** General postural training (*n* = 15) Rehabilitation (restitution)
Outcome measures	**ADLs:** Korean Modified Barthel Index **Adverse events:** Number of events **Motor (including balance):** Fugl-Meyer Motor Assessment-Lower Extremity Berg Balance Scale, Postural Assessment Scale for Stroke **Others:** Burke Lateropulsion Scale **Timing:** Immediately after intervention
Bergmann 2018[163]	
Participants	**Sense:** Somatosensation *n* = 38
Comparison	**Intervention 1 vs. active treatment 2**
Interventions	**Intervention 1:** Robot-assisted gait training Rehabilitation (restitution and substitution) **Intervention 2:** Non-robotic physiotherapy Rehabilitation (restitution)
Outcomes	**Mobility and Navigation:** Performance Orientated Mobility Assessment, Functional Ambulation Classification **Perception:** Subjective Visual Vertical **Other:** Scale for Contraversive Pushing, Burke Lateropulsion Scale
Carey 2011[74]	
Participants	**Sense:** Mixed (tactile and somatosensory) *n* = 50
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Sensory discrimination training Rehabilitation (restitution and compensation) **Intervention 2:** Exposure to tactile stimuli Rehabilitation (unclear)

Outcomes	**Perception:** Standardised somatosensory deficit [composite of texture discrimination (FMT), limb position sense (WPST) and tactile object recognition (fTORT)] **Adverse Events:** Numbers affected **Timing:** Immediately after intervention (and time points after partial crossover)
Chen 2012[154]	
Participants	**Sense:** Vision *n* = 11
Comparison	**Intervention 1 vs. active treatment 2**
Interventions	**Intervention 1:** Image drawing – global processing training Rehabilitation (restitution) **Intervention 2:** Image drawing – rote repetition training Rehabilitation (restitution)
Outcomes	**Perception:** Rey–Osterrieth Complex Figure, Modified Taylor Complex Figure, Medical College of Georgia Complex *Figures 1* and *2* **Timing:** Immediately post intervention, 2 weeks, 4 weeks
Cho 2015[66]	
Participants	**Sense:** Vision *n* = unclear – 27 'eventually completed the intervention and testing'
Comparison	**Intervention vs. no intervention**
Interventions	**Intervention:** NFB training Rehabilitation (restitution)
Outcomes	**Perception:** MVPT **Other:** Brain waves – electroencephalography (EEG) **Timing:** Immediately post intervention
Choi 2108[144]	
Participants	**Sens:** vision. Study also addresses postural balance and walking *n* = **28**
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** WVRT Rehabilitation (restitution) **Intervention 2:** General balance training **Classification of intervention:** Rehabilitation (restitution)
Outcomes	**Perception:** MVPT **Motor:** Berg Balance Scale **Mobility** and **Navigation:** 10 m Walking Test, Timed up and Go **Timing:** 1 week after intervention, 8-week follow-up
De Bruyn 2018[60]	
Participants	**Sense(s) addressed:** Somatosensory function *n* = 30
Comparison:	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Sensorimotor group in addition to conventional rehabilitation Rehabilitation (restitution) **Intervention 2:** Motor group in addition to conventional rehabilitation Rehabilitation (restitution)
Outcomes	**Perception:** Erasmus modified Nottingham sensory assessment, Perceptual Threshold of Touch, Texture Discrimination Test, Wrist Position Sense Test, Functional Tactile Object Recognition Test **Adverse events:** Number **Motor:** Action Research Arm Test, Fugl-Meyer Upper Extremity, Stroke Upper Limb Capacity Scale
Edmans 2000[60]	
Participants	**Sense(s) addressed:** Vision *n* = 80
Comparison	**Intervention 1 vs. Intervention 2**

Interventions	**Intervention 1:** Transfer of training perceptual treatment **Classification of intervention:** Rehabilitation (restitution) **Intervention 2:** Functional perceptual treatment Rehabilitation (compensation)
Outcomes	**ADLs:** Barthel ADLs Index, Edmans ADLs Index **Perception:** Rivermead Perceptual Assessment Battery **Motor:** Rivermead Motor Assessment Gross Function Scale **Other:** Length of stay, OT attendances, OT treatment time **Timing:** Immediately after treatment
Kang 2009[237]	
Participants	**Sense(s) addressed:** Vision *n* = 16
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Computerised visual perception rehabilitation with motion tracking Rehabilitation (restitution) **Intervention 2:** Computer-based cognitive rehabilitation program Rehabilitation (restitution)
Outcomes	**ADLs:** Modified Barthel Index **Perception:** MVPT **Cognition:** Modified Mental State Examination **Other:** Interest in intervention questionnaire **Timing:** Immediately after intervention
Kim 2015[201]	
Participants	**Sense(s) addressed:** Tactile *n* = unclear, but data for 30 participants was analysed
Comparison	**Intervention 1 vs. Intervention 2 vs. no treatment (across 3 arms)**
Interventions	**Intervention 1:** Pressure sense perception training on stable surface Rehabilitation (restitution) **Intervention 2:** Pressure sense perception training on unstable surface Rehabilitation (restitution)
Outcomes	**Mobility:** 10-m test, timed up and go **Perception:** Pressure error (dynamometer) **Motor:** Balancia, Functional Reach test **Timing:** Immediately after intervention (implied)
Koo 2018[187]	
Participants	**Sense(s) addressed:** Somatosensation *n* = 24
Comparison	**Intervention vs. control**
Interventions	**Intervention:** Anodal tDCS NIBS **Control:** Sham stimulation
Outcomes	**ADLs:** Korean version of Modified Barthel Index **Mobility and Navigation:** Functional Ambulation Category **Perception:** Erasmus MC modifications to the rNSA, Stereognosis Subscale **Adverse events:** Number **Motor:** Manual Function Test, Brunnstrom Classification **Sensory:** Semmes–Weinstein monofilament examination
Lee 2021[235]	
Participants	**Sense(s) addressed:** Somatosensation *n* = 25
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Robot-assisted therapy Rehabilitation (restitution and substitution) **Intervention 2:** Conventional therapy Rehabilitation (restitution)

Outcomes	**ADLs:** Modified Barthel Index **Perception:** rNSA Kinaesthetic subtest **Adverse events:** Number **Motor:** Fugl-Meyer Assessment, grip dynamometer, Box and Block Test **Sensory:** Semmes–Weinstein hand monofilament, **Other:** Surface electromyography **Timing:** Immediately after intervention
Lincoln 1985[150]	
Participants	**Sense(s) addressed:** Vision *n* = 33
Comparison	Intervention vs. control
Interventions	**Intervention:** Perceptual Training Rehabilitation (restitution) **Control:** Conventional therapy
Outcomes	**ADLs:** Rivermead ADLs scale **Perception:** Rivermead Perceptual Assessment battery **Timing:** Immediately after intervention
Park 2015[152]	
Participants	**Sense(s) addressed:** Vision *n* = 30
Comparison	**Intervention 1 vs. Intervention 2**
Interventions	**Intervention 1:** Computer-based cognitive rehabilitation training (CoTras) Rehabilitation (restitution) **Intervention 2:** Conventional cognitive rehabilitation Rehabilitation (restitution)
Outcomes	**Perception:** MVPT **Cognition:** Lowenstein Occupational Therapy Cognitive Assessment **Timing:** Immediately after intervention
Seim 2021[236]	
Participants	**Sense(s) addressed:** Tactile *n* = 16
Comparison	Intervention vs. control
Interventions	**Intervention:** Vibrotactile stimulation Glove Rehabilitation (restitution) **Control:** Sham
Outcomes	**Motor:** Voluntary angular range of motion **Sensory:** Semmes–Weinstein Monofilament Exam **Other:** Modified Ashworth Scale
Yang 2015[180]	
Participants	**Sense(s) addressed:** Somatosensation *n* = 12
Comparison	Intervention 1 vs. Intervention 2
Interventions	**Intervention 1:** Computer-generated interactive visual feedback training Rehabilitation (restitution) **Intervention 2:** Mirror visual feedback training Rehabilitation (restitution)
Outcomes	**Adverse events:** Number **Motor:** Berg Balance Scale, Fugl-Meyer Assessment **Other:** Scale for Contraversive Pushing
Yun 2018[181]	
Participants	**Sense(s) addressed:** Somatosensation *n* = 38
Comparison	Intervention 1 vs. Intervention 2

Interventions	**Intervention 1:** Robot-assisted gait training Rehabilitation (restitution and substitution) **Intervention 2:** Conventional physical therapy Rehabilitation (restitution)
Outcomes	**ADLs:** Korean version of Modified Barthel Index **Motor:** Berg Balance Scale, Fugl-Meyer Assessment **Adverse Events:** Number **Other:** Burke Lateropulsion Scale, Postural Assessment for Stroke, Somatosensory Evoked Potentials

FMT, Fabric matching test; fTORT, functional tactile object recognition test; WPST, wrist position sense test.

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HTA
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PHR

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