Enhancing problem-solving in acquired brain injury: A systematic review and exploration of a novel AI-based intervention

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Submitted in partial fulfilment of the requirements for the degree of

Doctorate in Clinical Psychology

School of Health and Wellbeing

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July 2026

Table of Contents

List of Tables 4
List of Figures 5
Acknowledgements 6
Chapter 1: Systematic Review 7
Abstract 8
Introduction 10
Methods 14
Results 20
Discussion 39
References 42
Chapter 2: Major Research Project 52
Plain Language Summary 53
Abstract 55
Introduction 56
Methods 61
Results 67
Discussion 79
References 85
Appendices 92
Systematic Review Appendix 92
Appendix 1.0 PRISMA 2020 Systematic Review Reporting Checklist 92
Appendix 1.1 Synthesis Without Meta-analysis (SWiM) Reporting Checklist 95
Appendix 1.2 Systematic Review Protocol & Amendments 97
Appendix 1.3 Systematic Review Database & Trial Register Search Strategies 98
Appendix 1.4 Systematic Review Hand Searches 124
Appendix 1.5 Characteristics of Excluded Borderline Studies 126
Appendix 1.6 Outcome Measure Selection Rationale 127
Appendix 1.7 Effect Size Calculations 129
Appendix 1.8 Examples of Solution Generation Components of Interventions 130
Major Research Project Appendix 132
Appendix 2.0 CONSORT 2025 Reporting Checklist for Reporting an RCT 132
Appendix 2.1 Open Science Information 135

Appendix 2.2 Project Approval Letters & Relevant Correspondence 136
Appendix 2.3 Confirmation of Non-Substantial Amendment from Sponsor 138
Appendix 2.4 Additional Materials 139
Appendix 2.5 Partial Approach and Consent to Contact Data 140
Appendix 2.6 Problem Statement Pilot Information 142
Appendix 2.7 Experiment Script Additional Detail 147
Appendix 2.8 Experimenter Support Intervention Checklist 148
Appendix 2.9 System Usability Scale 150
Appendix 2.10 Reflexivity Statement 151
Appendix 2.11 Content Analysis: Initial Reflections from Reading Transcripts 152
Appendix 2.12 Content Analysis Initial Coding Process 153
Appendix 2.13 Category Analysis: Codebook 157
Appendix 2.14 Solution Rating Examples 176
Appendix 2.15 Smart Steps AI Screenshots 180
Appendix 2.16 Appendix References 181

List of Tables

Chapter 1: Systematic Review

Table 1.1 Eligibility Criteria of Included Studies 15

Table 1.2: Participant Demographic Characteristics of Included Studies 23

Table 1.3 Summary of Interventions of Included Studies 26

Table 1.4 Breakdown of Studies and Results 31

Table 1.5 PEDro Scoring of Included Studies 36

Chapter 2: Major Research Project

Table 2.1 Baseline Characteristics of Participants 68

Table 2.2: Support and Prompts Provided During Trials 74

Systematic Review Appendix

Table 3.1 Backward Reference List Checking 125

Table 3.2 Characteristics of Borderline Studies 126

Table 3.3: Outcome Measure Selection Rationale 127

Major Research Project Appendix

Table 4.1 Partial Approach and Consent to Contact Data 149

Table 4.2 Content Analysis Codebook 165

Table 4.3 Content Analysis Coding Flags 183

List of Figures

Chapter 1: Systematic Review

Figure 1.1 Attention and Problem-Solving Framework 11

Figure 1.2: PRISMA Flow Diagram 21

Chapter 2: Major Research Project

Figure 2.1 Counterbalancing Procedure 65

Figure 2.2 Participant Flow Diagram 69

Figure 2.3 Mean Number of Researcher Prompts Required Across Sample and Smart Steps Experiment Trials 75

Acknowledgements

I would like to thank my Academic Supervisor, Prof Jon Evans, for his invaluable guidance, support, and expertise over the course of this project, as well as his broader dedication to the field.

I would also like to thank Dr Brian O'Neill, my Field Supervisor, for his crucial support in implementing the project, his innovative spirit in developing the Smart Steps AI application, and for the many interesting conversations we shared.

My sincere gratitude goes to all participants who generously gave their time to take part in this research, and for allowing me the privilege to get to know them.

I extend my thanks to the various recruitment sites and clinicians who supported recruitment, in addition to Bield, a local Support Provider, and Dr Barbara Dritschel, for sharing valuable information supporting the development of this project.

Further thanks are owed to Dr Paul Cannon, the School Librarian, who aided with the Systematic Review search strategy, and to my peers who volunteered their time and efforts to assist with piloting and outcome assessment.

And finally, I would like to thank my partner, Jessamyn, for her unwavering support of me, and to the friends I have made on this course, for their kindness and comic relief along the way.

Chapter 1: Systematic Review

The efficacy of problem-solving interventions in adults with acquired brain injury: A systematic review

Prepared in accordance with the author requirements for Neuropsychological Rehabilitation: https://www-tandfonline-com.ezproxy1.lib.gla.ac.uk/action/authorSubmission?show=instructions&journalCode=pnrh20#structure

Abstract

Background: The current review aimed to examine the efficacy of problem-solving interventions including solution-generation training, on problem-solving outcomes for adults with acquired brain injury (ABI).

Methods: Eligible studies were randomized controlled trials investigating rehabilitative interventions for problem-solving in adults with ABIs, containing explicit solution-generation training, and comparison to control group. Studies used validated outcome measures of problem-solving that included an element of solution generation. Studies including children, or pharmacological, medical, or physical interventions, and those targeting other cognitive processes were excluded. Four electronic databases (MEDLINE, CENTRAL, Embase, and CINAHL), and two trial registers (ClinicalTrials.gov, and WHO ICTRP), in addition to key journals, were searched between August and December 2025 to identify relevant papers. Risk of bias was assessed using the PEDro scale (Maher et al., 2003). Meta-analysis of results was inappropriate due to the heterogeneity of outcome measures and interventions within studies, therefore findings are presented as a structured narrative synthesis in line with SWiM guidelines (Campbell et al., 2020).

Results: Seven studies including 364 predominantly young-to-middle-aged (M = 41.7, SD = 9.6) and male (70.3%) adult participants with primarily mild-to-moderate (78.9%) traumatic brain injuries (78%) in the chronic phase, were included in analysis. Study quality was fair (M = 5/10) with notable variability (SD = 2.2, range = 1-8). Few outcome measures directly assessed solution generation, and most measured task completion in which solution generation is embedded. Findings indicated mixed and inconsistent support for improvements on measures, and effects were not consistently maintained. Greater, though still limited evidence, was found for task completion measures, and those with greater ecological validity.

Discussion: Overall, findings indicate that interventions may offer modest benefits, particularly for ecologically-valid tests, however this pattern is not consistent. Interpretation is limited by methodological shortcomings including underpowered analyses, and heterogenous outcome measures which are susceptible to task impurity. Future research

should attempt to establish greater conceptual clarity in the measurement of problem-solving and executive functioning, and attempt to isolate solution-generation more effectively.

Keywords: acquired brain injury, executive functioning, problem-solving, cognitive rehabilitation

Funding: no funding was received for this project.

Disclosure statement: there are no competing interests to declare.

Introduction

Acquired brain injury (ABI) refers to any brain damage experienced after birth that is not degenerative, hereditary or congenital in nature (Di Somma & Fleming, 2024). ABI encompasses both traumatic brain injury (TBI), caused by external force, and non-traumatic injury arising from internal causes, such as stroke, infection, and anoxia (Goldman et al., 2022).

ABI is a major global public health challenge, and a leading cause of mortality and disability worldwide (Davies et al., 2024) associated with long-term cognitive, psychological, and functional limitations. These include deficits in executive functioning (EF), memory, and attention (Mellon et al., 2015), increased mental health difficulties (Glintborg & Hansen, 2021), and reduced participation in meaningful life activities (Lannoo et al., 2004).

Executive functions

Among the cognitive sequalae of ABI, impairments in EF are particularly common and disabling (Chung et al., 2013). Executive functions are higher-order integrative cognitive processes that enable goal-directed behavior, and are key in the successful execution of activities of daily living (Tornås et al., 2019). These include processes such as working memory, inhibitory control and cognitive flexibility, which underpin complex behaviors such as problem-solving, initiation, and regulation (Lezak, 1982).

Problem-solving

Problem-solving (PS) is a key domain of EF, and refers to a set of cognitive and behavioral processes required to achieve a goal when a solution is not immediately apparent (D'Zurilla & Goldfried, 1971; Shallice & Burgess, 1996). Deficits in PS have been found to be among the most commonly reported areas of unmet need following ABI (Corrigan et al., 2004).

A prominent cognitive model of EF introduced by Shallice and Burgess (1996) describes the ‘supervisory attentional system’ to conceptualize processes involved in PS when encountering novel or complex situations. Within this model, PS is understood as a multi-stage process involving the generation of potential solutions, the implementation of a solution, and the evaluation of outcomes.

Building on this, Miotto et al. (2009) outlined an applied PS framework (Figure 1.1) that maps the various stages of PS onto a structured rehabilitation model, which additionally incorporates attention and impulsivity, related cognitive processes that impact successful PS.

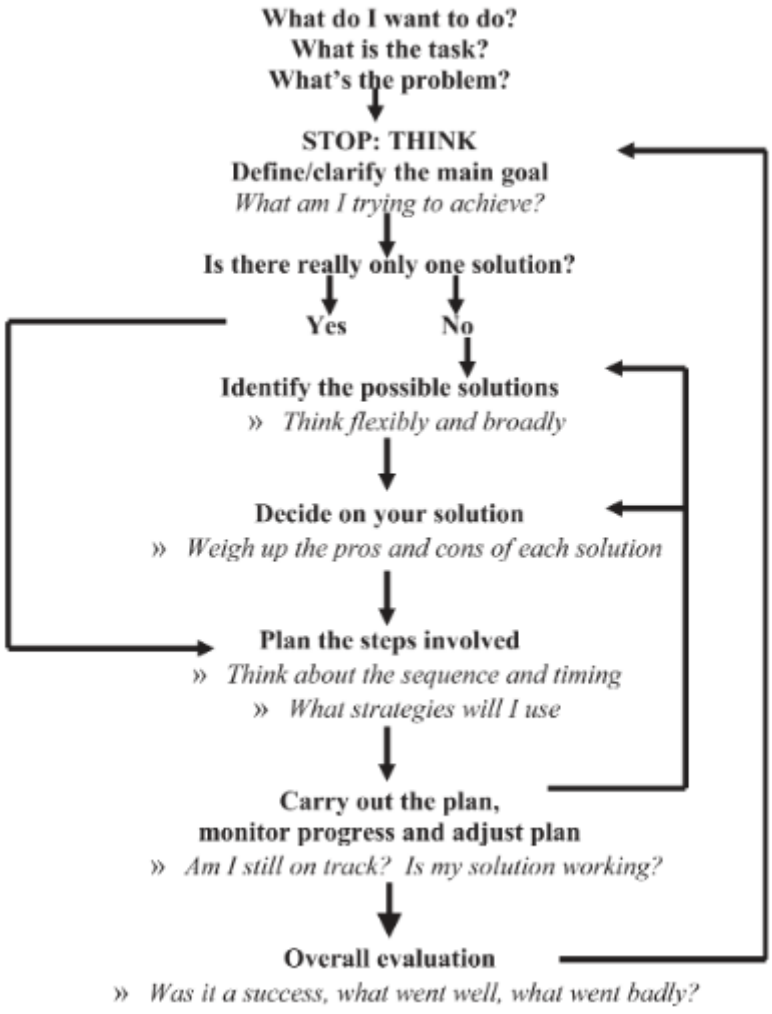

Figure 1.1

Attention and Problem-Solving Framework

Reprinted with permission from Dr E. Miotto (from: Miotto et al., 2009)

Difficulties in PS are nuanced. For example, an individual may successfully represent a problem, but struggle to generate solutions that adhere to resource restraints (Kennedy et al., 2008).

Cognitive rehabilitation

Cognitive rehabilitation describes therapeutic interventions designed to restore affected aspects of cognition (remediation approaches), or teach methods to compensate for cognitive deficits (compensatory approaches) (Davies et al., 2024).

In the context of PS, a restorative approach may involve repetitive drill-based training targeting underlying cognitive processes such as working memory. A compensatory approach might involve the use of an assistive technology, such as ProSolv (Powell et al., 2019) a smartphone application that supports users to remember steps for effective PS and provides personalized solution-lists.

Additionally, metacognitive strategies are key in EF rehabilitation, and are recommended as a core intervention in clinical guidelines (Cicerone et al., 2019; Jeffay et al., 2023). Metacognitive strategy training (MST) teaches individuals to develop mental strategies to enable more effective self-monitoring and self-control of cognition (Kennedy et al., 2008). An example of MST may involve encouraging recollection of memories to aid the solution of novel problems (Hewitt et al., 2006).

The International Classification of Functioning, Disability and Health (ICF; World Health Organisation, 2001) provides a biopsychosocial framework for functioning and disability. This highlights that rehabilitation is multidimensional and not restricted to improvement on standardized measures (impairment level), but also the ability to perform activities of daily living (activity level), and engagement in meaningful roles (participation level).

Previous reviews

Rehabilitation following brain injury has been extensively studied. Seminal work by Cicerone and colleagues (2000; 2005; 2011; 2019) provide comprehensive qualitative syntheses following TBI and stroke, in which MST for executive dysfunction is a practice standard in TBI rehabilitation. An umbrella review for TBI by Raymer et al. (2018) found beneficial outcomes for EF interventions, with strongest support for compensatory strategy training approaches including MST amongst other interventions such as goal management training (GMT; Robertson, 1996).

Quantitative syntheses of the literature have, however, produced mixed findings. Rohling et al. (2009) meta-analyzed the early work of Cicerone and colleagues (2000; 2005) and found a small-to-moderate effect size for EF and attention interventions combined (*M ES* = 0.35-0.38), however Chung et al. (2013) found limited evidence for improvements in EF outcomes in a Cochrane review of ABI.

A targeted review by Kennedy et al. (2008) focusing on PS, planning, organising and multitasking in TBI reported large but variable effects for MST, which were maintained over time, however MST did not demonstrate superiority over controls, and transfer to real-world functioning was limited.

To date, very few reviews have isolated PS interventions. Many existing reviews of interventions for EF frequently combine studies of interventions that primarily focus on goal execution or task management (as in GMT), and studies of interventions that target a broader range of PS components (such as solution generation). There is, therefore, a lack of clarity regarding whether interventions are effective in rehabilitating PS more broadly, including the solution-generation stage of PS.

The solution-generation stage of PS has been suggested by some to be the most complex, as it draws upon several cognitive functions, and is, therefore, highly vulnerable following brain injury (Miotto et al., 2009). Solution generation is closely aligned with the concept of means-ends analysis (Newell & Simon, 1972), where an individual encounters a problem and a desired goal state, but it is not immediately obvious how to close the distance between the two, requiring the generation of multiple solutions, and selection of an effective approach to reduce this discrepancy.

Objectives

The primary objective of this review was to examine the efficacy of rehabilitative PS interventions on PS outcomes for adults with EF or PS deficits following ABI. PS interventions are defined in this review as those that, at a minimum, include explicit solution-generation training, but may also support the implementation of solutions. Additionally, PS outcomes are defined as those containing either measures assessing solution generation, or task completion in which solution generation is required. This review additionally sought to answer whether treatment effects are maintained over time.

Methods

This review is reported in accordance with the PRISMA 2020 checklist (Page et al., 2021) (Appendix 1.0)

Eligibility criteria

Eligibility criteria were informed by the PICOS framework. See Table 1.1 for full criteria. Eligible studies were randomized controlled trials (RCTs) investigating rehabilitative interventions for PS or EF in adults with ABIs, containing explicit solution-generation training, and a control group receiving standard care or alternative intervention. Eligible studies additionally included validated outcome measures of PS assessing solution generation, but may also assess task completion.

Studies including participants with comorbid conditions were eligible if all participants had an ABI. Mixed samples were excluded. Eligible studies were written in English and published as full-text peer reviewed articles or registered trials with accessible data. No limits on publication date were applied.

Pharmacological interventions, medical interventions, and those intended to improve physical function were excluded, even if they included a cognitive component, in line with similar reviews (e.g., Davies et al., 2024).

Both ‘traditional’ neuropsychological outcome measures and ecologically-valid functional measures of problem-solving were eligible for inclusion. Subjective, self-report measures, were excluded as they do not typically capture solution generation. Additionally, insight difficulties in the ABI population are common (Prigatano, 1991), resulting in misleading results on such measures.

Inclusion Criteria	Exclusion Criteria
Full-text articles published in peer-reviewed journals or registered trials via trial registers or conference abstracts that contain usable data.	Other grey literature.
Studies including adult participants (≥18 years) with an ABI with or without comorbid conditions.	Participants <18 years old.
Studies containing PS or EF interventions, which also contain explicit training for the generation of solutions to problems, and may additionally include task execution interventions.	Interventions targeting other stages of PS (e.g. GMT), unless explicit solution-generation training is included.
Studies containing standardised and validated objective or functional outcome measures of PS.	Pharmacological, medical, or physical interventions.
Papers written in English language.	No outcome measures, non-validated measures, or subjective (self-report) measures.

Table 1.1

Eligibility Criteria of Included Studies

Information sources

Four electronic databases: MEDLINE, CENTRAL, Embase, and CINAHL, and two trial registers: ClinicalTrials.gov, and the World Health Organisation International Clinical Trials Registry Platform (ICTRP), were searched.

To identify additional studies, three of the most recent issues within eight key neurorehabilitation and neuropsychology journals, and reference lists of included articles, were hand-searched. Furthermore, first authors of included studies were contacted via electronic mail. No additional studies were identified using these approaches (Appendix 1.4).

Search strategy

A University of Glasgow Librarian was consulted on the search strategy and aided in the construction of the initial search. Search translations between databases were conducted by the Primary Reviewer.

Search strategies employed for each database and trial registry are detailed in Appendix 1.3. For Embase, Medline, and CINAHL, an RCT search filter published by the Scottish Intercollegiate Guidelines Network (SIGN; n.d.) was employed, and adapted to include conference abstracts as per Cochrane guidance (Chandler et al., 2019) to reduce publication bias.

Search strategies were validated by ensuring they identified records known to be relevant. Where this failed, terms were refined. For example, the RCT filter failed to identify some studies not explicitly indexed as RCTs, therefore, it was expanded to include variants of this term, improving sensitivity.

Selection process

Initially, all titles and abstracts were screened against the eligibility criteria by the Primary Reviewer (LW). Rayyan reference management software (Ouzzani et al., 2016) aided screening using machine learning algorithms to attribute a likelihood of inclusion rating to records yet to be screened, and flagging potential duplicate records.

A second reviewer (BON) independently screened an initial subset of 20 records which included a representative mixture of papers marked as included, excluded, and 'maybe' by LW. Blinded agreement was achieved for 17 out of 20 studies (85%) and disagreements were resolved through discussion.

Subsequently, 500 records were independently reviewed by BON, including all studies marked as included or 'maybe', and a random selection of records excluded by LW. Randomisation was achieved using the 'sampling' function on Rayyan. Inter-rater reliability was calculated using kappa (Cohen, 1960) which highlighted moderate agreement ($\kappa = 0.46$, observed agreement 81.6%). Discussion highlighted that discrepancies primarily related to the inclusion of broad cognitive rehabilitation interventions. Whilst BON adopted a more

conservative approach based on the likelihood of relevant outcome measures, a more inclusive approach was taken by LW. Discrepancies were resolved through discussion.

Data collection process

A standardised extraction template was created to capture relevant data from included studies. A second reviewer (JE) independently verified accuracy of extracted data from 10 studies.

Data items

Data were extracted for all PS outcomes which contained a solution-generation component, including task completion measures (where successful performance depends on effective solution generation). In studies reporting multiple appropriate measures, all outcomes were included, and for each, the sub-scale that most closely assessed solution generation was selected for analysis. In studies that reported only partial subscale data, authors were contacted to obtain full data. Where this was unavailable, the most appropriate existing subscale for each measure was selected.

Outcome measures varied in how directly they assessed solution generation, with few operationalising this directly. The purest example is the Means Ends Problem Solving Measure (MEPS; Platt et al., 1971), a neuropsychological test requiring individuals to describe relevant means to achieve an end goal from an initial state. More commonly, solution generation was one component within measures assessing problem-solving more broadly through overall task completion. For example, the Tower of London (Shallice, 1982) is a traditional neuropsychological test requiring the consideration of alternative 'moves' and strategies to reach a goal state. Additionally, the Multiple Errands Task (Shallice & Burgess, 1991), is a functional measure that makes demands on solution generation as individuals must generate and select strategies to achieve real-world goals.

Where multiple time points were reported, post-intervention outcomes were selected as the primary endpoint. Missing data were calculated where appropriate.

Risk of bias

Risk of bias was assessed using the PEDro scale (Maher et al., 2003), a commonly used tool in rehabilitation research reviews, which assesses key domains of internal validity, and statistical analysis, across 11 items including randomization, allocation concealment, and blinding. A final score out of 10 is calculated. The first item, which assesses the presence of eligibility criteria, is not counted. The average PEDro score is 5.2, with a standard deviation of 1.6 (PEDro, 2026).

The PEDro scale has demonstrated fair-to-good inter-rater reliability (Maher et al., 2003), with evidence supporting its validity as a measure of methodological quality of clinical trials (De Morton, 2009). Alternative risk of bias tools were considered including the Cochrane Risk of Bias 2 (RoB 2) tool (Sterne et al., 2019), and revised JBI critical appraisal tool for RCTs (Barker et al., 2023), which are more contemporary tools that provide domain-level risk of bias assessment. The PEDro scale was preferred owing to its prevalent use in rehabilitation research, and its concise and pragmatic nature, supporting comparisons between studies. Research has indicated individual PEDro item analysis may be more informative than a total score (Albanese et al., 2020), therefore, total scores are used in the current review to indicate overall methodological quality, alongside consideration of individual items.

A second reviewer (BON) independently rated 100% of included studies with excellent inter-rater agreement ($\kappa = 0.82$), and consensus was reached through discussion regarding disagreements.

Effect measures

Effect sizes were extracted from studies or calculated if sufficient information was reported, and converted into Hedges' *g* (Hedges, 1981) (given relatively small sample sizes) using an online calculator (https://statistics.tools/hedges-g-calculator).

Due to variation in reporting, effect sizes were derived from a mixture of post-intervention comparisons, change scores, and (in one study) within-group estimates (Appendix 1.7). Where sample sizes, means, and standard deviations were reported, Hedges' *g* based on change scores was calculated. Where these data were absent but an effect size was reported, this was converted to Hedges' *g*. Effect sizes were interpreted in line with the classification

system outlined by Cohen (1988) as Hedges' *g* is a small-sample correction of Cohen's *d* (Borenstein et al., 2021).

Synthesis methods

Meta-analysis was inappropriate due to the heterogeneity of outcome measures and interventions included in studies. Findings were instead presented using a structured narrative synthesis of effect sizes approach in line with SWiM guidelines (Campbell et al., 2020). Studies were grouped by outcome type and timepoint, and further categorised by methodological quality to facilitate comparison and interpretation of findings. Results are presented both in-text, and in tabular form.

Reporting bias assessment

Risk of bias due to missing results was not formally assessed due to the small number and heterogeneity of included studies.

Certainty assessment

An assessment of confidence in the body of evidence was not conducted due to the heterogeneity of interventions and outcome measures.

Results

Study selection

Records identified from database and trial register searches are summarised in the PRISMA flow diagram (Figure 1.2). Overall, 7,824 records were identified, of which 3,222 were flagged by Rayyan to be potential duplicates, and reviewed manually by the Primary Reviewer, resulting in the removal of 1,835 duplicate records. Following de-duplication, the Primary Reviewer screened 5,989 records against eligibility criteria. After second review at the title/abstract stage, 73 studies were sought for retrieval and assessed for eligibility. Sixty-five studies were excluded for various reasons (see below), and 7 studies (8 records) were included in the current review.

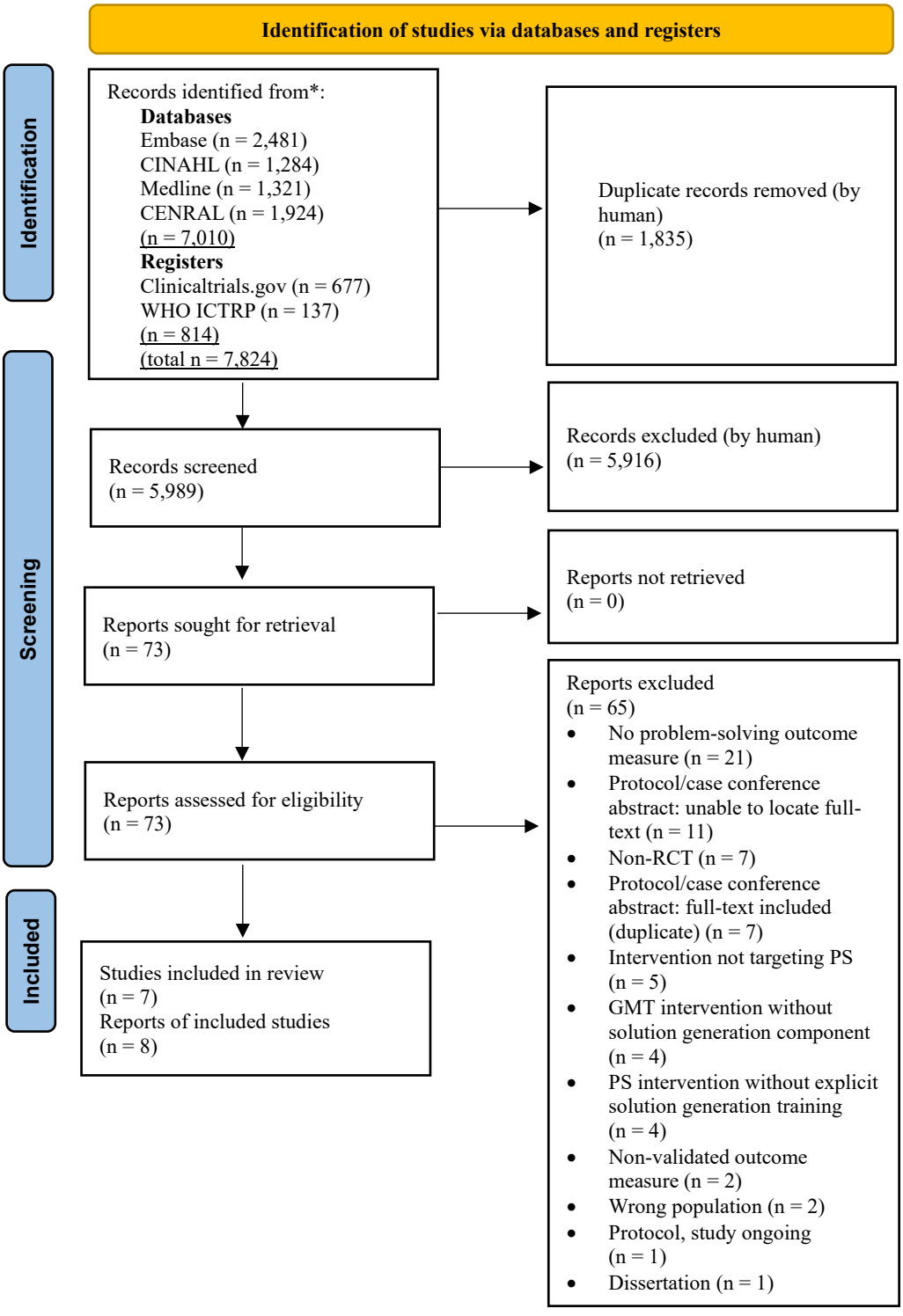

Figure 1.2

PRISMA Flow Diagram

Several studies initially appeared to meet inclusion criteria but were excluded at full-text screening. Borderline cases are detailed in Appendix 1.5, and key examples are outlined below.

Some studies included an intervention which primarily targeted solution implementation without an explicit solution-generation component. For example, Novakovic-Agopian et al. (2021) assessed a GMT intervention comprising attention and applied PS components, and whilst this included breaking goals into sub-goals, at no point were participants required to generate multiple solutions.

Other studies included relevant outcome measures but did not report usable data. For example, Cantor et al. (2014) administered the BADS, which includes multiple relevant outcome measures, however only a composite EF score was reported. Attempts to contact the authors to obtain specific sub-test scores failed, therefore this study was excluded.

Additionally, many registered trials and conference abstracts lacked usable data or associated publications. Despite searches via Google Scholar and attempts to contact authors, in all cases no full-text articles were obtained, and these records were excluded.

Study characteristics and results

Across seven studies published between 2003 and 2021 a total of 364 predominantly young-to-middle-aged (M = 41.7, SD = 9.6) and male (70.3%) adults were recruited primarily from outpatient care settings. All were in the chronic stage of brain injury (≥ 6 months post-injury), however time since injury varied (M = 3.4 years, SD = 3.5, range = 1 - 6.3 years). TBI was the dominant etiology (78%), however three studies included mixed ABI samples, which contained individuals with stroke (12.1%) and tumors (6.9%). Injury severity ranged from mild to severe, though was predominantly mild-moderate (78.9%). One study (Jak et al., 2019) included individuals with ABI and comorbid post-traumatic stress disorder (PTSD). Table 1.2 provides an overview of demographic characteristics of participants.

Total participants	*N* = 364
Age	*M* = 41.7, *SD* = 9.6
Gender*	Male: 256 (70.32%) Female: 109 (29.94%)
ABI etiology	TBI: 284 (78%) Stroke/vascular: 44 (12.1%) Tumor: 25 (6.9%) Other ABI: 11 (3%)
TBI severity**	Mild-moderate: 224 (78.9%) Severe: 24 (8.5%) Not reported: 36 (12.7%)
Time since ABI (years)	*M* = 3.4, *SD* = 3.5

Table 1.2

Participant Demographic Characteristics of Included Studies

* Approximate due to reporting limitations of studies

** Not delineated between mild and moderate in Jak et al. (2019), therefore severity is collapsed

Studies also varied with respect to the type of intervention assessed. In 4/7 studies, PS interventions were embedded within wider rehabilitative interventions: the Cognitive Enrichment Program (Cisneros et al., 2021), SMART-CPT (Jak et al., 2019), Mutifaceted Treatment of Executive Dysfunction (MTED; Spikman et al., 2010), and CogSMART (Twamley et al., 2014; Twamley et al., 2015). The remaining three studies targeted PS more narrowly albeit with additional components. These included explicit metacomponential PS and attention training (Fong & Howie, 2009), Attention and Problem Solving Treatment (APS; Miotto et al., 2009), and group PS and emotion regulation training (Rath et al., 2003). Most of these interventions were metacognitive in nature, though many also included remediation and compensatory components. Table 1.3 provides a detailed description of interventions.

In all interventions, solution generation was explicitly trained, with all but one adopting a 'brainstorming' (Osborn, 1953) approach, which emphasizes the generation of multiple ideas whilst withholding judgement, which is thought to constrain the process. In practice, the term

is typically used broadly to encompass subsequent strategy evaluation and selection. One study, Spikman et al. (2010), used a sub-goaling approach in addition to the anticipatory generation of solutions to potential obstacles through 'what if?' scenarios, representing a valid (albeit more constrained) form of solution generation.

Beyond solution generation, interventions tended to target the full range of PS stages. These commonly included interventions to improve problem definition, planning, and selection, implementation, monitoring, and evaluation of solutions, through metacognitive and strategy-based approaches.

Intervention delivery varied across studies. Most interventions employed a group format, whilst others were delivered one-to-one. Interventions were often manualized, but differed considerably in dosage, therapist background, and whether fidelity checks were reported. In several studies, the experimental interventions also included components of the control intervention.

All studies employed active controls, however these varied substantially in intensity, from psychoeducation, and treatment-as-usual to alternative rehabilitation approaches, which in several cases included cognitive training.

Studies predominantly operationalized PS outcomes using objective neuropsychological measures, with three studies also including functional measures.

Only a minority of studies used measures that directly assessed solution generation - Fong and Howie (2009) included both the MEPS, and the Social Problem Solving Video Measure (SPSVM; Kendall et al., 1997), and Rath et al. (2003) utilised the Problem-Solving Roleplay Test (PSRPT; Sherr et al., 1996). Of note, subscales that most closely aligned to solution generation were reported for the MEPS and SPSVM, whereas only a total score was reported for the PSRPT, limiting interpretation for this measure. In contrast, most measures required solution generation within tests that primarily assess task completion, such as the Six-Elements Test, the Wisconsin Card Sorting Test, and the Multiple Errands Task. More details of outcome measures and sub-scale selection can be found in Appendix 1.6.

Several reporting limitations were evident across studies, restricting interpretation of intervention effects. For example, Rath et al. (2003) reported within-subjects effect sizes for the intervention group only, and lacked formal between-group comparisons and point and variability estimates. Some studies also reported incomplete severity data (e.g. Rath et al., 2003; Jak et al., 2019), and follow-up data such as sample sizes (e.g. Fong & Howie, 2009) and attrition rates (e.g. Miotto et al., 2009). Table 1.4 provides a detailed breakdown of key information and results from included studies.

Two reports of one study by the same research team were included in this review (Twamley et al., 2014; 2015). Demographic data and post-intervention results were extracted from the former report, and follow-up data from the latter, however, both were rated separately for risk of bias due to heterogenous methodologies and outcomes.

Study	Intervention components & PS stages addressed	Solution-generation training	Intervention delivery	Comparator & delivery
Cisneros et al. (2021)	Cognitive Enrichment Program (CEP) EF module targeting EF difficulties arising from TBI and aging. Multimodal metacognitive training based on MTED and General Planning Approach (GPA) (Spikman et al., 2010), Problem-Solving Method (PSM; Von Cramon et al., 1991) and GMT. Addresses planning, solution generation, implementation, monitoring.	Brainstorming	Small groups (5-6 participants), 24x90-minute group sessions, 12-weeks. Delivered by an experienced Clinical Neuropsychologist. + Individual holistic rehabilitation (IHR)	IHR (usual care): 2-4 hours per week, 3-6 months. Individual intervention including physiotherapy, occupational therapy, excluding cognitive rehabilitation.
Fong & Howie (2009)	Metacomponential PS and Attention Training Structured PS training based on Sternberg's (1979) model of mental abilities, explicit teaching of metacomponents (stages of PS). Attention component based on theory of goal neglect (Duncan, 1986) and GMT.	Brainstorming, means-ends story writing.	Small groups (4-5 participants), 22x75-minute sessions, twice weekly, 15-weeks. Manualized intervention delivered by Occupational Therapists with extensive neurorehabilitation experience. All therapists followed manual. + Conventional Cognitive Training (CCT)	CCT: functional skills training involving compensatory approaches and cognitive drilling exercises.

	Addresses problem definition, planning, representation, self-monitoring (plus attentional component).			
Jak et al. (2019)	SMART-CPT = Cognitive Symptom Management & Rehabilitation Therapy (CogSMART) + Cognitive Processing Therapy (CPT) Compensatory cognitive training for attention, memory, and EF/PS, combined with trauma-focused therapy (CPT). Addresses goal-setting, planning, prioritising, brainstorming.	Brainstorming	One-to-one, 60–75-minute sessions, weekly, 12 weeks. Manualized intervention delivered by Clinical Psychologist trained in both interventions, with weekly supervision. 80%+ manual adherence scores across conditions.	CPT: psychoeducation for PTSD, cognitive theory, and treatment goals. Format matched to intervention (sessions 13 minutes shorter than SMART-CPT).
Miotto et al. (2009)	Attention and Problem-Solving Treatment (APS) Structured PS framework combining Problem Solving Therapy (PST; Von Cramon et al., 1991) with GMT, including metacognitive and attentional components.	Brainstorming	Groups (10 participants), 10-weekly 90-minute sessions, delivered by Neuropsychologists.	1.Information/education (IE): self-help booklet providing information about ABI, mental blackboard' and PS strategies. 2. Treatment-as-usual (TAU): excluding cognitive rehabilitation.

	Addresses problem awareness, definition, planning (solution generation), initiation, monitoring, evaluation.			
Rath et al. (2003)	Group Problem Solving Training Structured PS training including emotional regulation and logical reasoning components. Addresses problem definition, solution generation, implementation, evaluation (and emotion regulation component preceding PS).	Brainstorming	Small-groups (5-8 participants), 24, 2-hour, once-weekly sessions, (plus once weekly 1-hour consolidation sessions for innovative treatment group). Delivered by Psychologists. Sessions reviewed to ensure fidelity.	Conventional treatment: 24x2-3hour weekly sessions involving cognitive remediation and psychosocial groups (plus 1–2-hour weekly individual cognitive remediation). Broadly matched in intensity and format.
Spikman et al. (2010)	Multifaceted Treatment of Executive Dysfunction (MTED) Strategy-based EF training including GMT, PST, and GPA. Addresses problem definition, planning, (constrained) solution generation, implementation, monitoring (plus self-awareness, motivational and inhibitory components).	Sub-goaling plus anticipatory generation of solutions to obstacles	One-to-one, 20-24, 1-hour sessions, twice weekly, 3-months. Delivered by experienced Rehabilitation/Neuropsychologists, tailored to patients' needs. Psychologists received extensive training and monitored in 3-monthly meetings.	Computerized Cognitive Functioning Training (CGFT, Cogpack): Individually administered computer-based general cognitive function drilling. Format matched to intervention.

Twamley et al. (2014; 2015)	Cognitive Symptom Management & Rehabilitation Therapy (CogSMART) + Supported employment + Standard clinical care Multimodal structured training for post-concussive symptoms, memory, attention, learning and EF, with psychoeducation for TBI. Addresses problem definition, brainstorming, selection, implementation, evaluation.	Brainstorming	One-to-one, manualized 12-week intervention, integrated into 1-year supported employment programme delivered flexibly in community/clinical settings. Fidelity checked every 2 weeks – adherence rates between 90-100%. + supported employment + standard clinical care	Enhanced Supported Employment: delivered by Supported Employment Specialists, and matched for clinician contact. + standard clinical care.

Table 1.3

Summary of Interventions of Included Studies

Risk of bias

A full breakdown of PEDro scores for included papers is presented in Table 1.5. The mean PEDro score was 5, indicating fair quality, with notable variability across studies (*SD* = 2.2, range 1-8). All studies reported eligibility criteria, however this item is not counted in the total score. Whilst all studies randomly allocated participants, some methods were better than others, for example semi-randomization with matched pairs versus full randomization. Only one study employed allocation concealment. All but two studies contained groups that were similar at baseline. As participant and therapist blinding is unfeasible in studies that target the shaping of behavior (Kennedy & Turkstra, 2006), no studies achieved points for these items. Only three studies employed blinded outcome assessment. Outcome data for ≥85% of assigned participants was available for only four studies. Similarly, half the studies conducted an intention-to-treat analysis. All but one study reported between-groups comparisons and point and variability measures.

Study Characteristics & PEDro score	Study design	Sample size	Age ± SD (years)	Gender	Injury type/ severity	Average time since injury ± SD	Intervention & comparator	Outcome measures & subscales of interest	Selected subscale results at post	Longest follow-up results
Cisneros et al. (2021) Canada Older adults (inpatients/outpatients) 7/10	Semi-randomized controlled before and after trial	*N*=32 Cognitive Enrichment Program (CEP)=20 Individual holistic rehabilitation (IHR)=12	*M*=64.3±6.4	Males=19 (59.4%) Females=13 (40.6%)	TBI: Mild=21 Moderate=6 Severe=5	*M*=2.0±2.3 years	CEP Vs IHR	Adapted Six Elements Test (SET-A) Tackling the 6 subtasks D-KEFS Sorting Test Confirmed correct sort	SET-A Significant group x time interaction favoring CEP *F*=3.75, *p*=0.03, *g*=0.51, 95% CI [-0.21, 1.25] Sorting Test Non-significant group x time interaction *F*=2.45, *p*=0.096, *g*=0.75 [-0.01, 1.51]	6-months Results not maintained SET-A *g*=0.21 [-0.67, 1.09] Sorting Test *g*=0.85 [-0.06, 1.77]
Fong & Howie (2009) China Outpatients 4/10	Controlled trial with matched pairs, random assignment	*N*=33 Meta-componential approach (MCA) =16 Conventional Cognitive Training (CCT) =17	*M*=33.4±11.5	Males=27 (82%) Females=6 (18%)	'Moderate ABI' TBI=18 (55%) Intracerebral hemorrhage=9 (27%) Arterial-venous malformations =3 (9%) Brain tumor=2 (6%) Encephalitis=1 (3%).	*M*=12.3±13.3 months	MCA Vs CCT	Modified 6 Elements (M6E) Profile score Key search (KS) Profile score Means-ends Problem Solving (MEPS) Means	No significant differences: M6E *U*=77.0, *p*=0.079, g=0.58 [-0.10, 1.26] KS *U*=103.5, *p*=0.362, *g*=0.3 [-0.37, 0.97] MEPS *U*=77.0 *p*=0.139, *g*=0.56 [-0.12, 1.24]	3-months M6E Significant difference favoring experimental, *U*=20.0, *p*=0.03, *g* =-1.2 [-1.93, -0.46] KS Non-significant *U*=34.0, *p*=0.13, *g*=-0.75 [-1.46, -0.04]

Study Characteristics & PEDro score	Study design	Sample size	Age ± SD (years)	Gender	Injury type/ severity	Average time since injury ± SD	Intervention & comparator	Outcome measures & subscales of interest	Selected subscale results at post	Longest follow-up results
								Raven's Progressive Matrices (RPM) Profile score Social Problem Solving Video Measure (SPSVM) Planning	RPM *U*=116.0, *p*=0.470, *g*=-0.14 [-0.81, 0.53] SPSVM *U*=43.0, *p*=0.286, *g*=0.35 [-0.32, 1.02]	RPM Non-significant *U*=89.0, *p*=0.48, *g* = 0.11 [-0.57, 0.80] MEPS & SPSVM not assessed
Jak et al. (2019) USA Outpatient veterans 6/10	RCT	*N* = 100 Cognitive Symptom Management & Rehabilitation Therapy + CPT (SMART-CPT): 51 Cognitive Processing Therapy (CPT): 49	*M*=34.4±7.9	Males=89 (89%) Females=11 (11%)	'Mild to moderate TBI' and comorbid PTSD	Since most recent TBI *M*=5.4±3.5 years	SMART-CPT Vs CPT	Wisconsin Card Sorting Test-64 card version (WCST-64) Total errors score	WCST-64 Significant group × time interaction (across all time points) in favour of SMART-CPT group *b*=0.27, *t*[94.75]=2.44, *p*=0.017, *r*=0.24 Timepoint specific effect at post only: *g*= -0.73 [0.16, 1.30]	3-months Timepoint specific effect at 3 months: WCST-64 *g*= -0.48 [-1.16, 0.20]

Study Characteristics & PEDro score	Study design	Sample size	Age ± SD (years)	Gender	Injury type/ severity	Average time since injury ± SD	Intervention & comparator	Outcome measures & subscales of interest	Selected subscale results at post	Longest follow-up results
Miotto et al. (2009) Brazil Outpatients 4/10	Controlled crossover trial with pseudo-randomisation	*N*=30 Attention & PS group program (APS)=10 Information /education (IE)=10 Treatment-as-usual (TAU)=10	*M*=41.7±9.7	Males=15 (50%) Females=15 (50%)	Mild TBI=7 Meningioma=9 Low-grade astrocytoma =14	*M*=2.4±1.0 years	APS Vs IE Vs TAU	<u>WCST</u> Categories <u>Modified Multiple Errands Task (MMET)</u> Total score <u>Virtual Planning Test (VIP)</u> Total score	Control groups combined for analysis: <u>WCST</u> No Significant differences between groups at assessments 1 and 2 *H*=0.34, *p*=0.842, *g*=0.00 [-0.16, 0.86] <u>MMET</u> Significant difference between groups at assessment 1 and 2: *H*=8.47 *p*=0.015 *g*=0.82 [0.05, 1.59] Post-hoc tests revealing greater change in APS than IE *U*=17.5, *Z*=22.63, *p*=0.009 And TAU *U*=20.5, *Z*=22.33, *p*=0.02	6-months No significant results (insufficient data to calculate)

Study Characteristics & PEDro score	Study design	Sample size	Age ± SD (years)	Gender	Injury type/ severity	Average time since injury ± SD	Intervention & comparator	Outcome measures & subscales of interest	Selected subscale results at post	Longest follow-up results
									VIP No significant differences between groups at assessment 1 and 2 *H*=5.59, *p*=0.061, *g*=0.6 [-0.15, 1.36]	
Rath et al. (2003) USA Outpatients 1/10	RCT	*N*=60 Innovative group treatment (IGT)=32 Conventional treatment (CT)=28	*M*=43.6±11.2	Males=23 (38%) Females=37 (62%)	TBI: Mild=27 Moderate=11 Severe=19 Unavailable=3	*M*=48.2±58.4, months	IGT Vs CT	WCST Perseverative responses Problem Solving Roleplay Test (PSRPT) Total score	All within-groups: WCST Innovative group made fewer perseverative responses from pre-post *t*(24)= –2.16, *p*<0.05 *g*=0.35 [-0.16, 0.86] PSRPT Innovative group improved significantly following treatment, *t*(24)= –2.96, *p*<0.05, *g*=0.61 [0.09, 1.13]	6-months Treatment gains maintained (no data reported)

Study Characteristics & PEDro score	Study design	Sample size	Age ± SD (years)	Gender	Injury type/ severity	Average time since injury ± SD	Intervention & comparator	Outcome measures & subscales of interest	Selected subscale results at post	Longest follow-up results
Spikman et al. (2010) Netherlands Outpatients 8/10	RCT	*N*=75 Multifaceted Strategy Training (MST) =38 Computerized Cognitive Functioning Training (CGFT)=37	*M*=42.5±13.6	Males=66% (~50*) Females=33% (~25*)	TBI=43.75% (~33*) Stroke=43% (~33*) Other=13.25% (~10*)	*M*=59.5±84.8 months	MST Vs CGFT (Cogpack):	TOL Number correct Executive Secretarial Task (EST) Executive	TOL ANOVA revealed non-significant difference between MST and CGFT groups *g*= -0.3 [-0.75, 0.15]	6-months EST Significant difference between MST and CGFT groups at follow-up, favoring MST *T*=2.1 *p*<0.05 *g*=0.51 [0.03, 1.00]
Twamley et al. (2014; 2015) USA Veteran outpatients 4/10 (2014) 6/10 (2015)	Pilot RCT	*N*=50 enrolled (34 completed post-treatment) CogSMART:16 Control:18	*M*=31.9±6.8	Males=94% (~33*) Females=6% (~2*)	TBI: Mild=27 Moderate=7	Since most recent TBI (years) *M*=4.4±4.0	CogSMART Vs Enhanced supported employment + standard clinical care	WCST-64 Perseverative errors	From 2014: WCST-64 No significant difference between groups *t*(31)=0.9, *p*=0.40, *g*= -0.29, [-0.95, 0.37]	12-months From 2015: WCST-64 Non-significant group x time interaction: (*β*=0.04, *t*= 0.62, p=0.541 Timepoint specific effect size at 12-months *g*= -0.58 [-1.15, -0.01]

Table 1.4

Breakdown of Studies and Results

* Where only percentages are reported in-text, *n* has been calculated, '~' is used when result is not a whole number, indicating uncertainty.

Paper / PEDro item	1. Eligibility criteria	2. Random allocation	3. Concealed allocation	4. Baseline groups similar	5. Participant blinding	6. Therapist blinding	7. Assessor blinding	8. Outcome measures for ≥85%	9. Intention to treat analysis	10. Between groups comparisons	11. Point & variability measures	Total score
Cisneros et al. (2021)	✓	✓	✗	✓	✗	✗	✓	✓	✓	✓	✓	**7/10**
Fong and Howie (2009)	✓	✓	✗	✓	✗	✗	✗	✗	✗	✓	✓	**4/10**
Jak et al. (2019)	✓	✓	✗	✓	✗	✗	✓	✗	✓	✓	✓	**6/10**
Miotto et al. (2009)	✓	✓	✗	✗	✗	✗	✗	✓	✗	✓	✓	**4/10**
Rath et al. (2003)	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	**1/10**
Spikman et al. (2010)	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	**8/10**
Twamley et al. (2014)	✓	✓	✗	✓	✗	✗	✗	✗	✗	✓	✓	**4/10**
Twamley et al. (2015)	✓	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	**6/10**

Table 1.5

PEDro Scoring of Included Studies

Results of syntheses

Related research (Foley et al., 2003) suggests that studies may be broadly classified by their PEDro scores into four categories, providing an indication of their overall quality and reliability of results (in descending order):

Good quality (6-8)

- Spikman et al. (2010)
- Cisneros et al. (2021)
- Jak et al. (2019)
- Twamley et al. (2015)

Fair quality (4-5)

- Twamley et al. (2014)
- Fong and Howie (2009)
- Miotto et al. (2009)

Poor quality (<4)

- Rath et al. (2003)

The highest quality of evidence, from Spikman et al. (2010); Twamley et al. (2015); Jak et al. (2019); Cisneros et al. (2021), provides mixed support for improvements on PS measures. Whilst some studies demonstrate significant effects, these are not consistent across measures or studies. There is some indication that improvements may be more consistently observed on tasks with greater ecological validity (e.g. EST, SET-A), whereas more traditional neuropsychological measures (e.g. WCST, TOL) show inconsistent or null findings. Observed effects across studies are, however, modest and not consistently maintained over time, with limited replication to similar outcome measures.

Findings from 'fair' quality papers are largely consistent with those of higher-quality trials. Fong and Howie (2009) reported no significant differences between metacomponential PS training, and conventional cognitive training on all measures, including the MEPS and SPSVM, however at follow-up, the metacomponential group had a significantly higher profile score compared to control on the Modified Six Elements test. Similarly, Miotto et al.

(2009) found no significant differences on the WCST categories subscale, or VIP total score between the APS group and two control groups (combined), though a significant difference was found on the MMET total score at post, favouring the APS group. The results of this study should be interpreted with caution, as analyses were likely underpowered with a sample size of $n = 30$, and three groups, consisting of 10 participants each.

Lower-quality evidence (Rath et al., 2003) reports positive findings, with significant within-group reductions in perseverative errors on the WCST perseverative response subscale, and higher PSRPT total score following training, as well as evidence for maintenance of effects. Results were statistically significant for the experimental group, but not for the control group, however, the absence of between-group analyses, and non-equivalence of groups at baseline substantially limits the impact of these findings, which should be interpreted with caution.

Discussion

This review aimed to examine the efficacy of rehabilitative PS interventions including explicit solution-generation training, on PS outcomes in adults following ABI.

Interpretation & limitations of evidence

Overall, mixed and inconsistent support was found for the efficacy of interventions, with effects not consistently maintained. Evidence for more direct measures of solution generation was especially limited, whilst for task completion measures there was some evidence of improvement in a subset of studies.

Effects may be more consistently observed on tasks with greater ecological validity, however, this pattern was not consistent. One interpretation is that these interventions may support PS in tasks that more closely resemble real-world demands compared to abstract tasks presented in neuropsychological tests. Alternatively, ecologically-valid tests may involve tasks that more closely align with tasks used to illustrate strategies in interventions.

Studies in the current review included PS interventions that were often embedded within wider cognitive interventions, addressing multiple stages of PS simultaneously, aligning with a 'broad-brush' approach (Evans, 2005). This makes it challenging to conclude whether observed results were due to solution-generation components within PS interventions or due to other intervention components.

Relatedly, outcome measures primarily measured task completion, in which solution generation is embedded, rather than isolating this stage. Such measures inadvertently assess other cognitive processes, which speaks to a wider issue in EF research of 'task impurity' (Burgess, 2004) wherein measures lack specificity to isolate specific components.

Relatedly, both EF and PS are multi-component processes conceptualized in heterogenous and overlapping ways, complicating the interpretation of rehabilitation studies (Evans, 2005). Despite decades of extensive research, there remains little consensus around the definition and components of EF, which has resulted in some authors calling for a formalized ontology (Bunge, 2024).

Methodological limitations of evidence

Across studies, adequacy of power was difficult to evaluate, as none reported formal *a priori* power calculations. Small samples were observed in Cisneros et al. (2021), Fong and Howie (2009), Miotto et al. (2009), and Twamley et al. (2014); Twamley et al. (2015), and power issues were compounded by attrition, which was substantial in some studies (approximately 32% in control groups for both Rath et al., 2003; Fong & Howie, 2009). Although Jak et al. (2019), and Spikman et al. (2010) included larger samples, both compared experimental treatments to active controls, and therefore smaller effects would be expected (versus comparisons with less intensive controls such as psychoeducation). Taken together, these limitations, whilst common in rehabilitation research, indicate that studies may have been underpowered.

Additionally, various measures were employed across studies, including different versions of the same test (e.g. WCST, WCST-64), and subscale data was limited and heterogenous, with a tendency towards reporting summary scores. This is reflected in the EF literature more widely (Jurado & Rosselli, 2007) despite attempts by authors to remedy this by proposing process-level scoring methods (Anderson et al., 1998). This highlights the need for greater standardization in test-selection and subscale reporting.

Furthermore, included studies primarily targeted EF/PS at the level of impairment, which does not necessarily translate to meaningful changes at the activity or participation level (Davies et al., 2024). Although some studies incorporated broader outcomes, these were not included in the current review as they did not directly assess PS, limiting the conclusions that can be drawn about real-world outcomes.

Limitations of review processes

Refining the inclusion criteria to require explicit solution-generation training enabled a more precise focus on interventions covering all stages of PS including solution generation (which many previous reviews did not). However, this approach may have been overly restrictive. Interventions in which solution generation was trained more implicitly, embedded within other cognitive domains, or incorporated in functional tasks, were excluded, despite potential for conceptual overlap. This meant that interventions that may have more indirectly addressed solution generation were not considered. Additionally, studies that only focused on task management (such as GMT interventions), which may also benefit broader PS processes

through some aspects of the intervention (such as the STOP-THINK training element that may reduce impulsivity and increase the likelihood of engaging in a solution-generation process) were not included.

Additionally, only the Primary Reviewer screened full-texts. Second-reviewing would have strengthened reliability, particularly for borderline cases.

Implications

Despite mixed findings, there are indications that interventions may offer some benefit on tasks with more ecological validity. In addition, within the broader literature (that has included either mixed adult and adolescent samples, or adolescent only samples), there is some evidence for the efficacy of PS interventions targeting solution generation specifically, such as in a study by Hewitt et al. (2006), who found that recollection of autobiographical memories increases the number of steps in and effectiveness of solutions in a TBI adult and adolescent sample. Similarly, extensive work by Wade and colleagues highlights the efficacy of the Teen Online Problem-Solving (TOPS) intervention, which is identified as a practice standard for treating EF deficits in pediatric ABI (Wade et al., 2023).

Future research should better isolate underrepresented PS processes such as solution generation, using specific measures such as the MEPS. More broadly, greater conceptual clarity is required for the measurement of PS and EF.

Conclusion

Overall, findings suggest PS interventions may offer modest benefits, particularly for ecologically-valid tasks, though effects are mixed and inconsistent. Solution generation is an under-targeted stage of PS, and training is often embedded in wider interventions, which employ measures that suffer from task impurity. Accordingly, conclusions are tentative. The evidence base is limited by conceptual ambiguity, small samples, underpowered analyses, and heterogenous outcome measures. Further research is required to clarify the role of solution generation within PS, and to determine how best to target and rehabilitate this stage.

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Chapter 2: Major Research Project

Exploring the role of smart steps AI, a novel generative AI smartphone app, in augmenting problem-solving abilities for individuals with acquired brain injury

Prepared in accordance with the author requirements for Neuropsychological Rehabilitation - https://www-tandfonline-com.ezproxy1.lib.gla.ac.uk/action/authorSubmission?show=instructions&journalCode=pnrh20#structure

Plain Language Summary

Title

Can a smartphone app, Smart Steps AI', help people with brain injuries to solve problems, and what do they think about using it?

Background

An acquired brain injury (ABI) is damage to the brain caused by events like accidents, strokes, or illness. After an ABI, people often have difficulties with 'executive functions'. These are important mental skills that help us plan, make decisions, and control our emotions. A crucial executive function is problem-solving. Technology is sometimes used to support individuals after ABI, which is called 'assistive technology' because it helps people with everyday tasks.

Generative artificial intelligence (GAI) is a new technology that can do many things like answering complex questions, creating art and music, and communicating with users in a human-like way. 'Smart Steps AI' is a new smartphone app that uses GAI, and provides simplified spoken answers to questions, which it breaks down for the user, step-by-step. Smart Steps AI is intended to be a virtual care assistant for those with brain impairments.

Aims and questions

This study looked at two main questions:

- Does Smart Steps AI help people with brain injuries generate better solutions?
- What are people's experiences of using the app?

Methods

Who took part?

Twenty-three adults with moderate-to-severe ABI took part. They were recruited from hospital and neurological services. All had difficulties with executive functioning. Individuals were not included if they could not understand the study, or were unable to use the app, for example, due to severe communication difficulties.

What did they do?

Participants were asked to solve problems in two ways:

- Using Smart Steps AI
- Without using Smart Steps AI

Assessors then rated how effective the solutions were, and how many relevant steps they contained, which helped us assess the app's impact on problem-solving.

Participants also completed a short usability questionnaire, and took part in a brief interview about their experience of using SS.

Main findings

Using Smart Steps AI led to a small increase in the number of relevant steps in solutions, but this was not quite statistically significant. There was also no meaningful improvement in the effectiveness of solutions when using Smart Steps AI. In fact, solutions were slightly less effective when using the app.

Despite this, participants provided positive feedback about the app and thought it was a useful tool. Over a short period of time, participants needed little support to use it, suggesting the app is accessible, and can be learned quickly.

Conclusions

This study found limited evidence that Smart Steps AI helps those with ABI to solve problems more effectively. Despite this, participants liked using the app, and found it easy to use and useful. This suggests it could still be a helpful tool, even if it does not directly aid in generating better solutions. Importantly, because only a relatively small number of participants were recruited, the results might have been different if there were more participants.

Abstract

Background: Individuals with acquired brain injury (ABI) often experience cognitive deficits in executive functioning and problem-solving. The present study examined whether 'Smart Steps AI' (SS), a generative artificial intelligence-based smartphone app, augments problem-solving in adults with ABI, specifically at the solution-generation stage.

Methods: This study employed a mixed-methods, within-subjects experimental design with counterbalancing, and compared the effectiveness and number of relevant steps of participants' solutions when using SS (experimental condition) versus not using SS (control). Twenty-three adults with ABI were recruited across inpatient and outpatient neurorehabilitation settings. Independent assessors rated the effectiveness and number of relevant steps in solutions. The System Usability Scale was employed to assess overall usability, and a brief semi-structured interview was conducted to clarify participants' experiences of using the app.

Results: The number of relevant steps generated by participants whilst using SS were marginally higher ($M = 3.02$, $SD = 1.30$) than control ($M = 2.72$, $SD = 1.22$), and this approached significance ($p = 0.057$, $d = 0.37$). Effectiveness of solutions did not differ significantly between conditions (*n.s.,* $r = 0.07$). Participants found SS to have good usability, and most reported positive experiences with the app.

Conclusions: These results demonstrate the feasibility of SS as a usable tool within an ABI sample, but with limited direct impact on problem-solving deficits. Of note, analyses were underpowered.

Key words: acquired brain injury, executive functioning, problem-solving, cognitive rehabilitation, generative artificial intelligence, assistive technology for cognition.

Introduction

Background

Acquired brain injury (ABI) refers to any damage to the brain that occurs after birth and encompasses both injuries caused by external trauma (e.g. blunt force), and 'non-traumatic' internal disease (e.g. stroke) (Goldman et al., 2022).

Executive functioning (EF) is defined as 'top-down control processes essential for the regulation of goal-directed behaviour, such as goals formulation, anticipation of consequences, and the organization, monitoring, and adaptation of behaviour' (Tornås et al., 2019). It is estimated that 3 in 4 individuals with ABI will develop impaired EF (Chung et al., 2013), which is considered amongst the most debilitating cognitive impairments, impacting all areas of an individual's ability to function effectively across domains (Tsaousides & Gordon, 2009). This makes it an important rehabilitation target.

Problem-solving

Problem-solving (PS) is a crucial component of EF, and conceptualised by some authors as its primary function (Zelazo et al., 1997). PS can be broken down into steps - Zelazo et al. (1997) conceptualised four: problem representation, planning, execution, and evaluation. Difficulties can occur at any step, for example, a problem may be adequately represented, but a solution may be sequenced illogically.

Rehabilitation

Broadly speaking, rehabilitation interventions for cognitive impairments can be classified into either remediation or compensatory approaches (e.g. Tsaousides & Gordon, 2009). Remediation approaches attempt to restore or enhance functioning by practicing skills (e.g. drill and practice of cognitive tasks), whereas compensatory approaches make use of aids, or assistive technology for cognition (ATC), such as a reminders app on a smartphone, to help offset impairments (see Gillespie et al., 2012 for a review). In addition, the environment can be modified to provide compensatory support, for example, signs and labels placed around an individual's home.

In reality, compensation often takes the form of assistance by caregivers who offer verbal scaffolding for cognition by prompting and reminding, however this is time-consuming (O'Neill et al., 2018), costly (Oddy & da Silva Ramos, 2013), and often results in caregiver strain (Powell et al., 2017). ATC can circumvent these issues and support the generalisation of learned skills to more familiar settings (Powell et al., 2019).

Assistive technology for cognition

ATCs are categorised by their functions. For example, reminding technologies support prospective memory, time management, planning, and organisation, and may take the form of a calendar, or a device such as NeuroPage (Wilson et al., 1997). Micro-prompting technologies use feedback to guide users step-by-step through tasks that have multiple sub-tasks (Jamieson & Evans, 2014), and support the sequencing of tasks, such as household chores (Gillespie et al., 2012). For example, the GUIDE system uses audio prompts to check whether users have completed sub-tasks before providing subsequent prompts (O'Neill et al., 2010).

In one review, ATCs were found to effectively support planning, time management, memory, attention, experience of self, and emotion, with 63% of studies targeting reminding and prompting interventions (Gillespie et al., 2012). In another meta-analysis, a large effect size (d = 1.27) was found for the efficacy of ATCs for individuals with memory impairments (Jamieson et al., 2014).

Evidence for ATCs targeting PS is lacking. One ATC which supports problem representation and planning is ProSolv, a smartphone application that allows users to remember steps for effective PS, and create personalised solution-lists (Powell et al., 2019). The results of this study, which included a feasibility study, between-subjects group study, and single case study, were, however, mixed. In the feasibility study and case study PS improvements were observed, however in the main group study no statistically significant results were found, likely due to methodological limitations. Overall, PS appears to be an often-overlooked target for compensatory aids.

Generative artificial intelligence

Generative artificial intelligence (GAI) is a type of AI that can generate new 'human-like' content that has not been programmed into the system. The most popular example of GAI is the Chat Generative Pre-Trained Transformer chatbot (ChatGPT), publicly released in 2022.

Since its inception, GAI has proven to be a powerful tool with widespread application across various fields. In healthcare, GAI has been rapidly integrated in various capacities and is radically transforming the field (Rabbani et al., 2025). For example, a recent review found that GAI is being used in healthcare in a supportive capacity across a multitude of tasks including clinical documentation, patient communication, clinical decision making, patient monitoring, drug discovery, medical education, and mental health support (Rabbani et al., 2025).

Evidence regarding the use of GAI as an ATC remains preliminary, indirect, and largely confined to non-clinical populations. Therefore, its efficacy in supporting cognition, especially in impaired populations, remains unclear.

A recent exploratory case study highlighted the barriers those with cognitive impairments face when using GAI, such as complex interfaces, abstract language, and lengthy and unstructured responses (Francisco et al., 2025). This highlights inequitable access to GAI for a population that may uniquely benefit from it, and the need for adaptations to enable participation.

Smart Steps AI

'Smart Steps AI' (SS; McDonagh et al., 2026) is a novel smartphone app and micro-prompting technology built on ChatGPT but specifically adapted for the brain injury population. The app has a basic design interface, simplifies output, is voice-controlled (thereby removing the need to type), and presents solutions step-by-step, which are prompted by the user at their own pace.

Theoretically, SS is best understood as offering compensatory PS support, rather than remediating underlying abilities. With reference to multi-stage models of PS such as Zelazo et al. (1997), SS may reduce demands across problem representation, planning, execution,

and evaluation by generating, selecting, and sequencing solutions, and scaffolding implementation of solutions.

An initial pilot study with single-case experimental design (SCED) involving a woman with a TBI and frontal lobe damage aimed to assess the feasibility of SS in supporting activities of daily living and occupational performance (McDonagh et al., 2026). The experiment used an ABA design and assessed whether use of SS improved sequencing on a cooking and clean-up task. Although sequencing scores improved across phases, this was consistent with a learning effect, and could not clearly be attributed to SS. The authors concluded that whilst SS demonstrates potential as an adjunct to therapy it cannot be recommended as a substitute. The study also highlighted challenges with acceptability as the participant expressed frustration with the app, which struggled to understand her speech, in addition to safety concerns relating to the app's omission of safety and hygiene steps. The authors highlighted the limitations of the SCED design.

Rationale for current research

SS is novel technology which specifically adapts GAI for the brain injury population but requires further testing to assess its efficacy in supporting PS, and its acceptability as a tool.

Additionally, the rapid pace of technological advancement can lead to the obsolescence of effective solutions as technology becomes unsupported, such as in the case of NeuroPage (Wilson et al., 1997; Callaway & Liddle, 2023). As such, research of effective ATC needs to keep pace with these technological changes. In a similar vein, the World Health Organisation Global Report on Assistive Technology (2022) includes within its ten recommendations: 'investment in research, innovation, and an enabling ecosystem' for assistive technology, encouraging the development of new products that utilise emerging technologies, including AI.

SS may be an effective and acceptable ATC for supporting PS in individuals with an ABI, as it can understand, process, and produce language efficiently in a human-like and user-friendly manner, has access to a broad knowledge base from which to draw solutions, and is highly customisable to individual needs. Therefore, this research project examined whether SS can effectively support PS deficits in ABI, specifically at the solution-generation stage, and therefore whether it may be considered an ATC.

Objectives

The primary research question examined whether SS augments solution generation in individuals with moderate-to-severe ABI with EF difficulties. The independent variable was condition, with two categories: participants generating solutions unassisted (control condition), and generating solutions with the aid of SS (experimental condition). The dependent variables were the number of steps in, and effectiveness of, solutions, and the time taken to generate a solution.

It was hypothesized that the number of steps in, and effectiveness of, solutions, would be greater when using SS versus not using SS, based on previous work using a related PS task in which a brief metacognitive planning support intervention improved both plan effectiveness and number of relevant steps (Hewitt et al., 2006)

The secondary research question assessed participants' experience of SS. Previous research has emphasized the need for assistive technology to be easy to use and personalised to the needs of users (Brandt et al., 2020). Various studies have also demonstrated that involving users in its design reduces the chances that products are abandoned (e.g., Phillips & Zhao, 1993). This is important, as despite research on its effectiveness, uptake is sometimes poor (Evans et al., 2003). Accordingly, an additional qualitative component was employed to assess overall satisfaction, accessibility, and usability of SS, and to capture participants' perceptions of the impact of SS on their PS ability.

Methods

Patient and public involvement

Two patients with an ABI residing at an inpatient neurorehabilitation centre were consulted on key study documents. A demonstration of the app was provided, and the general aims of the study outlined. This resulted in accessibility amendments to the Participant Information Sheet. Patient feedback also highlighted design feedback for future iterations of the app, such as adding a 'stop' or 'close' button.

Study design

The study employed a mixed-methods, within-subjects experimental design, in which participants were randomised to one of four counterbalanced orders (see Figure 2.1).

Changes to trial protocol

A minor amendment was submitted to the ethics board and approved (Appendix 2.3) to use Content Analysis (Krippendorff, 2018) rather than Thematic Analysis (Braun & Clarke, 2012) to analyse qualitative interview data. This was due to a lack of 'richness' of responses, and data that lent itself more to frequency-based analysis.

Research setting

Participants were recruited from five sites within Glasgow, and North Lanarkshire, Scotland comprising two inpatient neurorehabilitation centres, two inpatient wards and an outpatient rehabilitation centre. Inpatients were tested in quiet rooms, and outpatients either at the outpatient centre, or the Clarice Pears building at the University of Glasgow.

Eligibility criteria

The inclusion criteria were having a moderate-to-severe ABI with clinician-identified problems with EF (either by formal neuropsychological assessment or clinical judgment), and capacity to consent to participation. Individuals receiving ongoing (or prior) rehabilitation at the time of the study were eligible as many would be expected to continue to experience PS difficulties. Whether an individual had received prior rehabilitation was recorded.

Exclusion criteria included lacking capacity to consent to the research, or presence of severe aphasia, severe dysarthria, or other impairments which precluded effective use of SS. Additionally, those who required an interpreter to understand English were excluded.

Participants were recruited by purposive sampling. Clinicians within recruitment sites identified those who met eligibility criteria and clarified whether they wished to participate. Contact details of those who expressed interest were forwarded to the researcher who contacted potential participants by phone and answered any questions. Those who agreed to participate were then invited to the assessment session where consent was obtained.

Intervention & comparator

Problem statement development

Problem statements were adapted from questions asked to staff by individuals with cognitive difficulties, including some with dementia (collated by Bield, a local support provider), and others with ABI (within one recruitment site). Microsoft Copilot was additionally used to generate problem statements.

Problem statements were piloted using a similar method to Noreen et al. (2015). Two independent raters (Trainee Clinical Psychologists) rated 25 problems for difficulty and solution openness. Average ratings were combined into a composite score, and the 10 most difficult problems with the most open solutions were selected as the final set (reflecting likely real-world use of SS). One further problem was selected as a demonstration item, and two as sample items. Further information is provided in Appendix 2.6.

Smart Steps AI (version 1.0.7) ran on a study smartphone (Samsung Galaxy A12) with Android operating system (version 13). The app was operated by the participant, with the support from the Principal Researcher when required. A brief demonstration of the app was provided prior to the experiment. A full version of experiment materials/script is included in Appendix 2.4.

During the control condition, participants were presented with five problem statements one-by-one, and asked to solve each problem, orally describing their solution.

In the experimental condition, participants were presented with five different problems in the same manner, and for each problem asked to use SS to generate a solution. After SS finished its solution, participants were then asked to orally describe their solution.

A support checklist was developed which enabled the Principal Researcher to record support provided during the experiment beyond the initial demonstration of the app (Appendix 2.8). This included, for example, prompting participants to speak more clearly, and writing problem statements on paper to reduce the memory load involved in remembering them.

Outcomes

To assess the primary research question, spoken solutions were recorded and transcribed into text, and the time taken between the Principal Researcher finishing asking the problem statement to the participant beginning to outline their solution was measured using Microsoft Teams. Two independent and blinded raters (Trainee Clinical Psychologists, separate to pilot raters) rated the number of relevant steps, and effectiveness of solutions on a 7-point Likert scale on Microsoft Excel. The effectiveness scale, used in related research, has demonstrated sensitivity to the effects of brain injury (Dritschel et al., 1998) and change following an intervention (Hewitt et al., 2006). The scale included three anchors: 1 = 'not at all' effective, 4 = 'moderately' effective, and 7 = 'extremely effective' (see Appendix 2.14 for scored examples).

The secondary research question was assessed using a brief semi-structured interview, and the System Usability Scale (SUS; Brooke, 1996), which has good reliability ($\alpha = 0.91$; Bangor et al., 2008) and concurrent validity ($r = 0.82$; Bangor et al., 2009). The SUS was administered directly after the experiment, followed by the interview last. Interviews followed a brief schedule (see Appendix 2.4) designed to clarify participants' experiences of using the app, which took approximately five minutes to administer, and assessed likes and dislikes, difficulties encountered, perceived impact on PS, and suggested improvements.

Neuropsychological assessments

To characterise the sample, assessments of PS and EF were conducted using neuropsychological assessments:

Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 2004)

- Zoo Map
- Modified Six Elements
- Dysexecutive Questionnaire (DEX; self-report version)

Delis-Kaplan Executive Function System (DKEFS; Delis et al., 2001)

- Tower Test

In addition, the Test of Premorbid Functioning (TOPF; Wechsler, 2009) was administered to estimate premorbid intelligence. Tests were administered by the Principal Researcher, Assistant Psychologists, and the Field Supervisor, within testing sites. If tests were conducted within the last year, these scores were used.

Sample size

A comparable study investigating PS in a TBI sample found an effect size of $dz = 0.6$ (Hewitt et al., 2006). With an alpha level of 0.05, G* Power version 3.1.9.7 (Faul et al., 2007), indicated that 24 participants were required to achieve a power of 0.80. To be conservative, the study aimed to recruit 32 participants, matching the sample size of Hewitt et al. (2006).

Counterbalancing

The experiment was counterbalanced with two question sets (A and B), and two condition sequences (SS or control first), comprising four orders to which participants were randomly allocated using an online random number generator (https://www.calculatorsoup.com/calculators/statistics/random-number-generator.php). For every 4 participants, an order number between 1-4 was generated. As the Principal Researcher tested all participants, and the order sequence was generated before enrolment, allocation was not concealed.

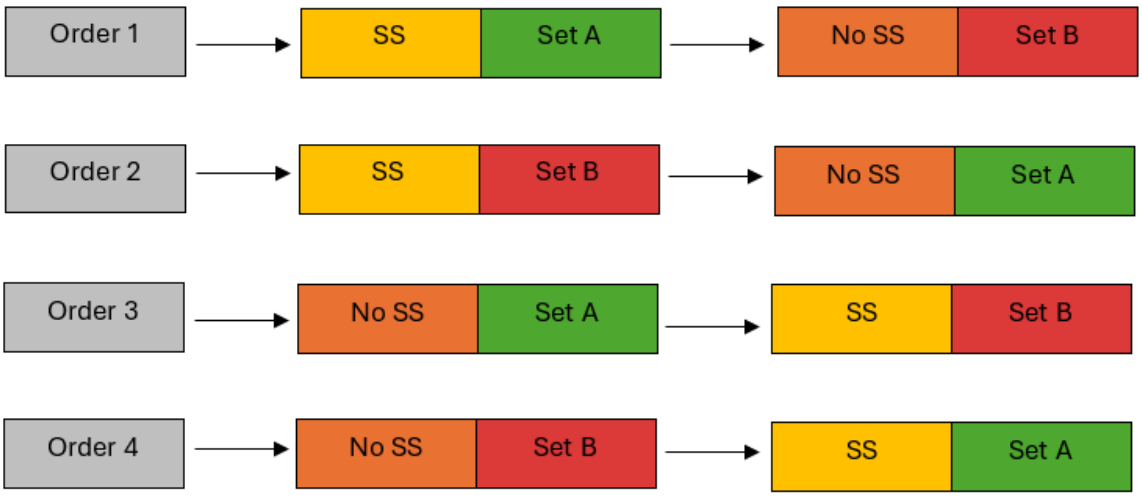

Figure 2.1

Counterbalancing Procedure

Blinding

Outcome assessment was blinded – raters were unaware whether solutions were generated during SS or control conditions. Participant blinding was not feasible since use of SS resulted in condition allocation being evident.

Statistical methods

The main analysis compared the number of relevant steps and effectiveness ratings of solutions, and time to generate solution between the experimental and control conditions. Following normality checks, paired samples t-tests were conducted for the number of steps, and time to generate solutions, and a Wilcoxon signed rank test was conducted for effectiveness ratings of solutions. All participants with complete data for both conditions were analysed. Three participants with missing SS condition data were excluded (see Recruitment).

Additional exploratory analyses were conducted to assess the correlation between level of impairment (defined by a mean z-score of EF tests), and difference in scores between experimental and control conditions for effectiveness and (separately) number of steps.

To answer the secondary research question, average SUS scores were calculated, and brief interview responses were transcribed and analysed using inductive Conceptual Content Analysis (Krippendorff, 2018) following Erlingsson and Brysiewicz (2017). Initially, recordings were transcribed verbatim and read twice to obtain an overall sense of the data. The meaning unit of words or short phrases relevant to the research question was selected, and an initial coding scheme was created. All transcripts were then re-read and refined codes were created and tested in an iterative fashion. A codebook was also created. Final categories were then developed by grouping related refined codes. Coding and analysis were conducted by the Principal Researcher only. One participant was excluded from Content Analysis due to minimal responses and exiting the room immediately following interview.

Three additional exploratory post-hoc analyses were conducted. A simple regression analysis examined the level of support required (mean number of prompts) over problem statements in which SS was used (trials). An order effect analysis was conducted to examine whether the order of condition, or question sets, influenced number of relevant steps, and effectiveness, difference scores. Relatedly, a correlational analysis assessed whether participant age was associated with number of relevant steps, and effectiveness, difference scores.

All quantitative analyses were conducted using SPSS version 29.0.2.0, and Microsoft Excel and Microsoft Word were used for data entry and qualitative analysis. Statistical significance level was set at the 0.05 alpha level.

Results

Participants

The sample comprised 19 males (82.6%) and 4 females (17.4%), with a mean age of 52.6 years (*SD* = 9.1, range = 40), and a median time since injury of 2.1 years (IQR = 0.72-4.24), within the chronic stage. The most common injury type was TBI (56.5%), followed by stroke (26.1%), hypoxic-ischaemic (8.7%), toxic-metabolic (4.3%), and infection-related (4.3%). See Table 2.1 for a full breakdown of baseline characteristics.

Most participants (69.6%) were current inpatients in neurorehabilitation settings actively receiving rehabilitation. Living situation of participants varied, with most living in hospital (39.1%), followed by supported accommodation (21.7%), independently (21.7%), and with family (17.4%).

The sample was ethnically homogenous with 95.7% describing themselves as ‘white'. In addition, the majority reported they did not use any form of ATC (91.3%).

Age	*M*=52.6	*SD*=9.1	Range=40		
Sex	Male: 19 (82.6%)	Female: 4 (17.4%)			
Ethnicity	White: 22 (95.7%)	Mixed: 1 (4.3%)			
ABI etiology	TBI: 13 (56.5%)	Stroke/ cerebrovascular: 6 (26.1%)	Hypoxic ischaemic: 2 (8.7%)	Toxic-metabolic / substance related ABI: 1 (4.3%)	Infection-related: 1 (4.3%)
Time since BI (years)	Median = 2.1	IQR = 0.72–4.24			
Use of ATC	Yes: 2 (8.7%)	No: 21 (91.3%)			
Living situation	Hospital: 9 (39.1%)	With family: 4 (17.4%)	Supported accommodation: 5 (21.7%)	Independent: 5 (21.7%)	
Prior cognitive rehabilitation	Yes: 13 (56.5%)	No: 10 (43.5%)			
Recruitment site	Inpatient: 16 (69.6%)	Outpatient: 7 (30.4%)			
Neuro-psychological test scores	TOPF *M*=97.98 *SD*= 16.65	Zoo Map *M*=1.48 *SD*=1.30	Six-Elements *M*=2.57 *SD*=1.22	Tower *M*=8.09 *SD*=4.04	DEX *M*=24.96 *SD*= 12.70

Table 2.1

Baseline Characteristics of Participants

TOPF PIQ = Test of Premorbid Functioning predicted intelligence quotient score, Zoo-Map = profile score, Six-Elements = profile score, Tower = scaled score, DEX = Dysexecutive Questionnaire raw score

Figure 2.2 illustrates the flow of participants through the study. Partial approach, consent to contact, and participation data can be found in Appendix 2.5.

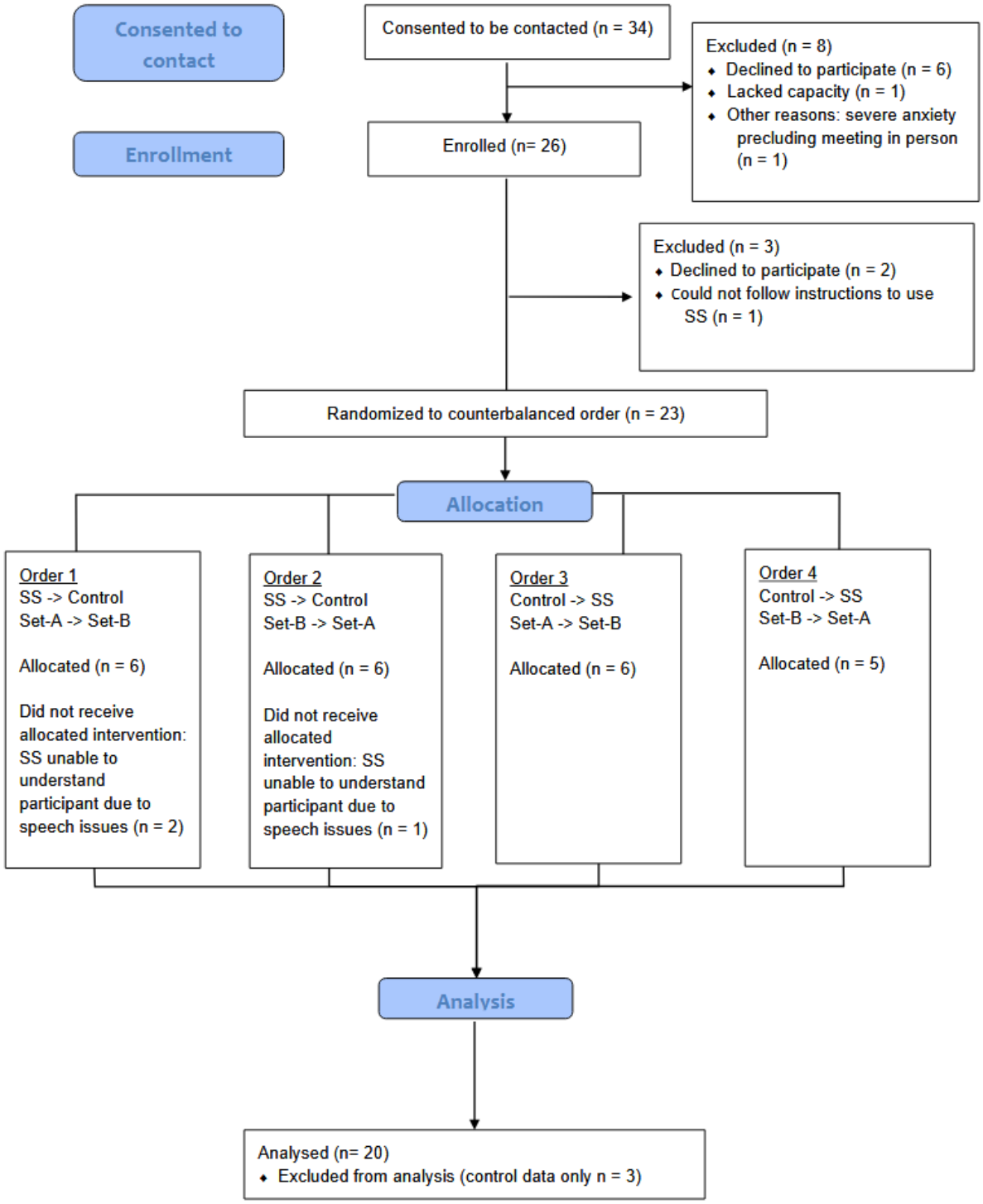

Figure 2.2

Participant Flow Diagram

Recruitment

Recruitment ran from 15/09/2025 to 27/02/2026. In all but two cases, there was only one meeting with the participant. In the time available for recruitment, it was possible to randomize 23 participants. Three participants who met eligibility criteria initially and enrolled into the study were unable to complete the SS condition as the app could not reliably understand their speech. These participants still completed the control condition (relative to their counterbalanced order) but were excluded from all analyses except qualitative and SUS analyses.

Intervention and comparator delivery

In all cases, the Principal Researcher (a Trainee Clinical Psychologist) delivered the experiment in a room one-to-one with the participant. The Field Supervisor (and co-creator of the app) supervised administration of the experiment for the first participant.

During the control condition, a standardized period of time between asking the problem statement and allowing the participant to answer was intended to be introduced to match experimental and control conditions. In reality, it was unclear how long this period should be since the amount of time using the app varied considerably between (and sometimes within) participants. Instead, during the control condition, participants were asked to 'take whatever time [they] need[ed]' to answer the question, which maintained a more naturalistic approach to testing. No time limit was applied to how long participants could use the app. A script was followed for consistency (Appendix 2.4).

Primary research question

Inter-rater reliability

Inter-rater reliability of problem solution scoring was calculated using a two-way random effects model with absolute agreement, which indicated moderate agreement (Koo & Li, 2016) for both number of relevant steps (ICC = 0.71, 95% CI [0.55, 0.81], $p < .001$) and effectiveness ratings (ICC = 0.70, 95% CI [0.63, 0.76], $p < .001$). Accordingly, number of relevant steps and (separately) effectiveness scores for the two raters were averaged relative to condition.

Number of relevant steps

Difference scores for the number of relevant steps between SS and control conditions were normally distributed, as indicated by non-significant Shapiro-Wilk test $W(20) = 0.98$, $p = 0.943$ and visual inspection of boxplot and histogram. No outliers were identified.

As it was hypothesised that the number of steps in solutions would be greater in the SS condition, a one-tailed paired samples t-test was conducted to compare the average number of relevant steps in participants' responses between conditions. Overall, participants generated slightly more relevant steps in the SS condition ($M = 3.02$, $SD = 1.30$) compared with control ($M = 2.72$, $SD = 1.22$), $t(19) = 1.66$, $p = 0.057$, $d = 0.37$ 95% CI [-.087, .820], which approached significance, with a small-to-medium effect size (Cohen, 1988).

Effectiveness analysis

To compare the average effectiveness scores of solutions between conditions, a Wilcoxon signed rank test was conducted. Because effectiveness of solutions was predicted to be greater in the SS condition, a one-tailed test was specified. This demonstrated effectiveness ratings did not significantly differ between the SS (Median = 3.3, IQR = 3.0–4.5) and control conditions (Median = 3.7, IQR = 2.6-4.2), $Z = 0.322$, *n.s.,* $r = 0.07$). Of note, median effectiveness was numerically greater in the control condition, indicating observed effect was in the opposite direction than predicted, but the effect size was very small.

Time analysis

The time taken for participants to provide a solution after the Principal Researcher finished reading the problem statement was calculated. It was acknowledged, however, that this measure was severely confounded with experimental condition, since during the SS condition participants had both considerably longer to consider a solution while using SS, and when asked to provide a solution, had just heard SS outline its own solution, facilitating conditions for faster solution generation. Accordingly, no results for this analysis are reported.

Exploratory analyses

Impairment correlation

Correlational analyses explored whether solution effectiveness, and number of steps, difference scores, were associated with level of EF impairment, defined by the mean z-score across EF sub-tests: Zoo Map, Six-Elements, and Tower test. Standardised z-scores for the BADS sub-tests were calculated relative to normative control group means and standard deviations. Tower test scores were converted using the normative test mean (10) and standard deviation (3).

Shapiro-Wilk tests indicated that EF composite scores $W(20) = 0.96$, $p = 0.579$ and effectiveness difference scores $W(20) = 0.97$, $p = 0.841$ were normally distributed. A Pearson's r test found no significant association between the two, $r(18) = 0.19$, $p = 0.425$. Similarly, number of relevant steps difference scores were not significantly correlated with EF composite scores $r(18) = 0.19$, $p = 0.423$.

Order effect analysis

To explore whether the order of conditions or question sets influenced outcomes, participants were grouped according to condition order (SS or control first), and question order (set A vs set B first).

Mann-Whitney U tests indicated no significant effects of condition order on effectiveness difference score, $U = 47.00$, $Z = -0.19$, $p = 0.849$, or number of relevant steps difference score, $U = 40.50$, $Z = -0.69$, $p = 0.492$. Similarly, there was no effect of question order on effectiveness difference score, $U = 42.00$, $Z = -0.61$, $p = 0.544$, or relevant steps difference score, $U = 45.50$, $Z = -0.34$, $p = 0.733$. These results suggest that neither condition order nor question set order impacted performance, indicating successful counterbalancing.

Age analysis

A correlational analysis was run to explore whether age of participants was associated with performance between conditions. Age was normally distributed $W(23) = 0.97$, $p = 0.776$, and there was no significant association with number of relevant steps difference score $r(18) = 0.19$, $p = 0.412$, or effectiveness difference score $r(18) = -0.07$, $p = 0.756$.

Support checklist analysis

Support prompts provided over all trials are summarised in Table 2.2, where one trial corresponds to use of SS during sample problems 1 and 2 (trials 1 and 2 respectively), or during SS condition experiment problems (trials 3-7). Over all trials combined, participants required an average of 2.53 prompts (*SD* = 2.70), including 4.33 prompts on sample trials (*SD* = 3.06), and 1.71 prompts (*SD* = 2.06) on experiment trials.

Support provided	Occasions	% of trials
Prompted to say ‘next’ to progress SS through solution	62	42.5%
App restarted after failing to finish solution when instructed	57	39%
Question repeated	54	37%
App restarted following prompt (e.g. to speak more clearly)	54	37%
Technical prompt (e.g. tap microphone icon)	23	15.8%
Reminded to say ‘I’m finished’ when sufficient information to solve problem	20	13.7%
Questions written for participant	19	13%
Prompted to speak faster	19	13%
Prompted to speak clearer	18	12%
Prompted to use app	12	8.2%
Prompted to say ‘next’ or ‘continue’ when app did not understand participant enunciating the other	9	6.2%
Prompted to ask approximately same question to SS as being asked by experimenter	8	5.5%
Emotional support/encouragement provided	5	3.4%
Prompted to answer experimenter instead of app	4	2.7%
Discouraged asking additional questions to SS	3	2.1%
Reminded that problem asked to SS need not be exactly same as asked by experimenter	3	2.1%

Table 2.2

Experimenter Support Provided Across Trials

A simple linear regression model indicated that as participants progressed from sample trials through SS trials, significantly less prompting was required $F(1,144) = 38.70$, $p < 0.001$, explaining 21% of the variance. Trial number significantly predicted mean prompts required ($B = -0.61$, $SE = 0.098$, $t = -6.22$), indicating that, on average, participants required 0.61 fewer prompts with each successive trial (see Figure 2.3).

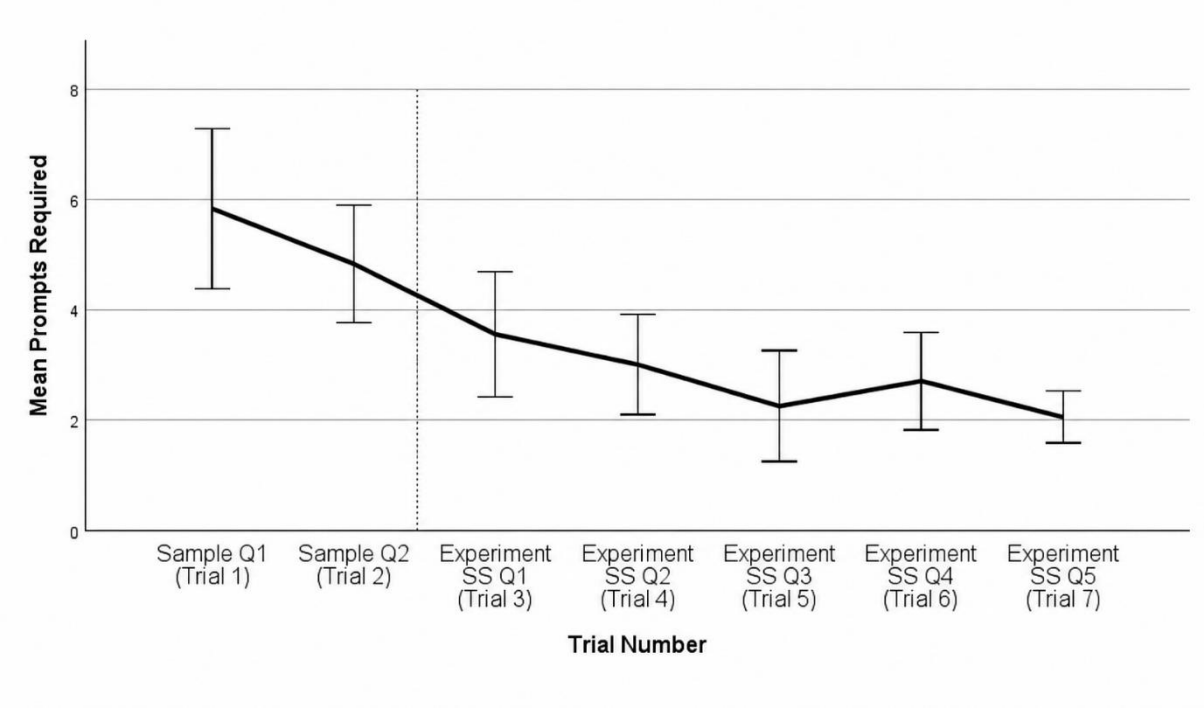

Figure 2.3

Mean Number of Researcher Prompts Required Across Sample and Smart Steps Experiment Trials

(error bars: +/- 2 SE)

Secondary research question

System Usability Scale

The mean usability SUS score was 78.5/100 (*SD* = 15.6, range = 50), indicating 'good' perceived usability (Bangor et al., 2009). Sixteen (69.6%) participants scored above the accepted 'average experience' benchmark of 68, and thirteen (56.5%) above the 'good experience' benchmark of 80 (Lewis & Sauro, 2018). Seven participants scored below the average benchmark (*M* = 58.9, *SD* = 7.5). Of these, three participants completed only the control condition due to speech difficulties precluding completion of SS condition, two of whom provided the lowest scores in the sample of 50. The remaining four participants scored on average 62.5 (*SD* = 6.1), remaining slightly below the 'average' cut off. Taken together, this indicates that the system was broadly deemed usable, with a minority of participants experiencing accessibility limitations that impacted usability.

Content Analysis

Content Analysis identified 9 categories relating to participants' experience of SS. Categories and codes, along with frequency counts reflecting the percentage of participants expressing each code are summarised below. See Appendices 2.10-2.13 for full codebook, illustrative quotes, and supporting materials.

Categories:

- Technical Performance and Faults
- Usability
- Personalization and Feature Requests
- Quality of Solutions
- Usefulness
- Impact on PS
- Suitability and Risk
- Affective and Relational Experience
- Engagement Intentions

Within the Technical Performance and Faults category, participants described both strengths and limitations in performance. Most frequently, participants reported SS had difficulties understanding their speech (43%). A quarter of participants made positive comparisons between SS and other software, such as Google (26%). Some characterised the app as being fast (13%), and flexible (13%), whereas others reported it did not complete its solution when instructed to (13%), or described it as slow (9%) or unfinished (9%). One participant noted SS began responding before they could finish asking the problem (4%).

With regards to the Usability category, most participants highlighted the app's ease of use (83%) with only one individual describing it as difficult to use (4%). Some also noted its accessibility (26%), its ability to understand intended meaning (13%), and that it was easy to learn (9%), or tailored to those with cognitive impairments (4%). However, some participants indicated they would need more time to become familiar with the app (17%) or would require further support to use it effectively (13%). One participant stated that difficulties encountered when using the app were to be expected during first time use (4%).

Regarding the Personalisation and Feature Requests category, participants suggested a range of possible features. These included integrating other services (such as Google Maps) (9%), providing on-screen text to accompany spoken solutions (9%), adding an alarm (4%), integrating adaptive features based on usage (4%), offering multiple solutions (4%), supporting the user's positive emotional experience (4%), and calling the user by their name (4%). In addition, some participants highlighted the need for improved speech recognition (13%) and faster operation (9%).

Regarding the Quality of Solutions category, participants indicated mixed views. Some described solutions as good (17%), clear (9%), detailed (9%), and concise (9%). In contrast, others described responses as too basic (17%), or lengthy (4%) and one participant reported the app asked too many, or unimportant, questions (4%). Three participants indicated they liked that solutions were broken into steps (13%).

Within the Usefulness category, approximately half the sample described finding SS useful (52%), while two participants felt it would not be useful to them personally (9%). Others identified potential in the app (13%), and one participant indicated the solutions provided by SS aligned with their own PS approach (4%).

Regarding the Impact on PS category, two-thirds perceived the app positively impacted their PS ability (65%), or prompted new ways of thinking or reflection (65%), whilst a quarter believed the app had no impact on their PS (26%).

With regards to Suitability and Risk, one participant reflected on whether the app was suitable for some people with ABI, such as adults with incapacity (4%), adding that it might increase risk for some (4%), however, they also reflected that the app might decrease risk or protect them from harms in other ways (4%). Another participant highlighted the apparent lack of harms from using the app (4%).

Within the Affective and Relational Experience category, three-quarters of participants expressed (non-specific) positive opinions about the app (74%). Only one participant expressed a (non-specific) negative opinion (4%). Five participants described the app as offering a sense of companionship (17%), with one indicating they liked that the app was non-judgemental (4%). Others described the app as clever (13%), and suggested it could help

with the adjustment to having a brain injury (9%). One reflected on the importance of asking the right questions to get useful answers (4%). In addition, two participants disliked the voice of the app (9%), whilst one liked it (4%).

With regards to Engagement Intentions, a quarter of participants explicitly expressed they intended to use the app (26%), and one intended to recommend the app to others (4%). Another expressed a desire to continue to ask the app questions (4%).

Although not a category, 43% of participants reported no dislikes of the app, 26% reported no difficulties, and 22% had no suggestions for its improvement. A further 26% of participants indicated they did not have enough time using the app to respond to a particular question (e.g. dislikes, impact on PS).

Discussion

This study aimed to investigate whether SS augments solution generation in individuals with moderate-to-severe ABI and EF difficulties, and therefore whether it may be considered an ATC. The secondary research question examined participants' overall experiences of SS to clarify usability and acceptability of the app, and capture participants' perceptions of its impact on their PS.

The main analysis found that use of SS aided in the generation of slightly more relevant steps in solutions compared with control, and this finding approached significance. In contrast, the effectiveness of solutions was comparable between conditions, with ratings marginally higher in the control condition. This suggests that SS may support the structure or quantity of responses over solution quality. Researcher support was primarily operational/technical, so may have enabled app use without improving solution quality. Exploratory analyses indicated that condition order, question set order, level of EF impairment, and age of participants did not influence outcomes. Overall, the hypothesis that SS would improve the number of steps and effectiveness of solutions was not supported.

Although not specifically measured, considering the time outlay required to use SS, this indicates limited additional value for SS as an ATC to support solution-generation.

Usability and acceptability

Despite this, results indicate participants quickly became proficient in using the app despite a shorter training period than the pilot (McDonagh et al., 2026). In addition, SUS scores and qualitative analysis indicate the app was generally well received by participants, contrasting opinions of the participant in the pilot (McDonagh et al., 2026). Indeed, most participants in the current study described positive experiences (74%) with the app, expressing that it was an easy to use (83%), and useful (52%) tool, and in many cases, positively impacted their problem-solving (65%) and prompted novel ways of thinking (65%). In addition, 43% of participants reported no dislikes, 26% reported no difficulties, and 22% had no suggestions for improving the app. These findings lend support to the app's usability for the ABI population, especially as the sample was comprised of relatively middle-aged (M = 52.6, SD = 9.1) individuals who may be less digitally literate than their younger counterparts (Lee & Tak, 2022).

Consistent with the pilot study (McDonagh et al., 2026), use of SS in the current study was not fully independent, but required support, and in practice, functioned as a therapist-supported intervention. This limits conclusions about independent use, and continues to position SS as an adjunct to, rather than replacement for, clinical input. Additionally, similar to the pilot study, some participants, especially those with strong regional accents, or mild speech difficulties, indicated the app failed to understand their understand speech (43%). Despite this, only 13% explicitly highlighted the app should improve its speech recognition, indicating that whilst SS struggled at times to recognize speech (and for some it failed completely), participants still had generally positive experiences.

One possible explanation for the discrepancy between positive subjective appraisals but limited objective impact on solution-generation is that participants appeared to be impressed by the app, which they may have conflated with judgements that it impacted their PS. Similar to virtual-reality interventions, SS' novelty and perceived sophistication may have increased motivation and enjoyment – two key aspects of effective rehabilitation (Pietrzak et al., 2014; Sharma et al., 2025).

An interesting exploratory analysis (out with the scope of this thesis) would be to compare the similarity of solutions provided by SS to solutions generated by participants after using SS. This would clarify whether participants chose their own solutions, or attempted to reiterate or condense solutions provided by SS. It is perhaps likely participants did not choose SS' solutions, or failed to relay them effectively, given lower effectiveness ratings in this condition. In addition, solutions generated by SS were often lengthy as they were articulated step-by-step. In a population that struggles with memory deficits (Jamieson et al., 2014), this may have resulted in difficulties remembering solutions, or ineffectively remembering the gist of solutions. In turn, this may have impacted solutions negatively, for example, by being sequenced ineffectively. This is, however, hypothetical, and future research may seek to clarify this.

Relatedly, after hearing SS' solutions, participants may have felt it artificial to repeat these, potentially introducing demand characteristics. This reflects a broader limitation in the ecological validity of the study. Participants were instructed to use the app in a way that differs from its intended real-world use. Specifically, they were instructed to imagine they

were solving problems in the real world, rather than implementing the solution in reality. This may have influenced performance and limits the generalizability of findings.

Limitations

There are several limitations of this study. Of particular importance, the main analysis was underpowered. This is unlikely to have impacted the results of the effectiveness analysis, but may have brought the results of the relevant steps analysis into statistical significance. Nevertheless, the observed effect size for number of relevant steps was small-to-medium, and in the absence of a minimally clinically important difference, even if powered adequately, it would be difficult to determine whether this effect represents a meaningful improvement in real-world solution-generation.

In addition, the control condition could have been improved. In the current study, participants were asked to 'take whatever time [they] need[ed]' to answer the question, which maintained a more naturalistic approach to testing, however, it meant that participants often responded quickly. Future studies may consider including a further control condition which employs a standardized period of time before participants can answer, which would control for impulsivity.

Whilst the preponderance of white participants is representative of the wider Scottish population (National Records of National Records of Scotland, 2024), the sample was disproportionately male (82.6%), and largely comprised of inpatients (69.6%), which limits the generalisability of results.

Qualitative findings should be interpreted with caution, as interviews were conducted, transcribed, and coded by the Principal Researcher, who also delivered the intervention. This may have introduced demand characteristics and experimenter effects. For example, participants may have felt less able to offer critical feedback about SS, particularly participants in one recruitment site who were familiar with the study's Field Supervisor, and co-creator of SS.

Content Analysis was used to analyse interview data due to a lack of 'richness' in the data. This mirrors Fong and Howie (2009), who found that comments provided about their interventions in an ABI sample were 'very general'. This may reflect cognitive difficulties

observed in this population, however, greater richness may have been obtained if the interview did not take place after around an hour of sustained attention required for the experiment. In addition to fatigue, the Principal Researcher may have influenced participants' approach to the interview by framing it with statements such as 'this will take 5 minutes'. Whilst these estimations were based on completed interviews and designed to facilitate engagement, they may have anchored participants' expectations to provide less depth in their answers.

In addition, whilst problem statements were piloted, their content was similar. Most notably, three questions involved planning a social event. This may reflect the more open and challenging nature of social problems, and highlights the trade-off between including distinct but simpler problems (and therefore less representative of problems people might use SS for) and including several more open and difficult questions which are conceptually similar. In hindsight, including a broader range of problems reflecting social difficulties commonly faced by people with ABI such as interpersonal conflict (Fong & Howie, 2009), may have been beneficial.

The measurement paradigm of the study also contains validity limitations. Available measures of solution generation are limited, and effectiveness and number of relevant steps were selected as outcomes based on their use in related research (e.g., Hewitt et al., 2006), and practical relevance to the current study design. However, these measures are not well validated, and may not fully capture solution generation. This is particularly relevant for number of relevant steps, where higher scores may reflect more granular solutions, but also verbosity, or superfluous responding.

A further limitation is that the counterbalancing order was not concealed from the Principal Researcher. Difficulties with recruitment meant that participants were enrolled consecutively, however allocation concealment could have been improved by revealing the order of the next participant only at the time of enrolment.

A final limitation that applies to all ATC studies and affects rehabilitation studies more broadly is that participant blinding was not possible, which may have resulted in participants modifying their behaviour in accordance with expectations of the study's perceived aims.

Clinical relevance

The study's results highlight both potential benefits and challenges of using GAI in individuals with ABI. Previous research found generic GAI chatbots like ChatGPT have not been shown to be suitable for individuals with cognitive deficits (Francisco et al., 2025). In the current study, an ABI sample generally found SS to be acceptable and useful, suggesting that, with support, SS appears to be an acceptable way for people with ABI to access GAI.

Quantitatively, whilst SS did not improve effectiveness of solutions, it showed some indication of slightly increasing the number of relevant steps in solutions, which suggests that SS may still have value as a supported adjunct to rehabilitation. Qualitative results also highlight additional perceived benefits, including fostering a sense of companionship, which may contribute to broader goals around independence and quality of life. However, AI use in this population requires caution, particularly given safety issues, speech-recognition errors, perseverative responding, and the need for therapist support and monitoring.

Future research

The broader literature highlights a discrepancy between performance on impairment tasks and real-world functioning (Kennedy et al., 2008). Additionally, as highlighted by Cicerone et al. (2019) 'cognitive rehabilitation should…directly apply compensatory strategies to functional contexts'. Whilst the pilot attempted this, its conclusions were limited owing to a sample size of $n = 1$. SS should therefore be tested in a real-world functional context with a larger sample, and include assessment of PS at different stages (e.g. task execution).

Relatedly, future studies could also examine the impact of SS on other markers of rehabilitation such as the activity or participation level (World Health Organisation, 2001) for example, by increasing independence in completing activities of daily living (e.g. shopping), or facilitating resumption of previously abandoned activities. This is important as rehabilitation should prioritize meaningful change, not simply improvements on standardized measures (Cicerone et al., 2019).

Smart Steps AI – future development

This study provides valuable data for the future development of SS. In particular, improved training in speech recognition is required to enable equitable access to those with speech difficulties. Specifically, training to recognize prompting phrases is required, as in many

cases, the app did not understand unless the ‘t’ in ‘next’ was enunciated clearly. Where necessary, speech recognition could be trained on an individual user’s speech to facilitate more accurate recognition. The app should also provide a longer period for the user to ask questions, or be more robust to pauses in speech to avoid cutting the user off. It should also manage perseveration more effectively - in its current form, the app sometimes provides steps indefinitely, which become increasingly extraneous and inappropriate.

Additionally, whilst the app provides guardrails for some safety concerns, such as allowing the user to input allergies, it must handle safety concerns more robustly - as also highlighted in the pilot (McDonagh et al., 2026). For example, in the current study, the problem ‘how would you decide whether to replace or repair a broken microwave?’ was replaced as a sample item during piloting because on one occasion the app prompted the user to disassemble the microwave.

Conclusion

In conclusion, this study found limited and mixed evidence that SS supports the solution-generation stage of PS. Whilst SS showed some indication of increasing the number of relevant steps in solutions, this did not translate into improved effectiveness of solutions. Despite this, participants found it an acceptable and usable tool, and became quickly proficient in its use despite limited training. Results should be interpreted with caution as analyses were underpowered. Future development of the app must overcome key barriers to use, most notably understanding and responding to the user’s speech, and handling safety concerns and perseveration more effectively.

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Appendices

Systematic Review Appendix

Appendix 1.0 PRISMA 2020 Systematic Review Reporting Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	7
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	8
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	10-13
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	13
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	14-15
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	16
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix 1.3
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	16
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	16-17
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	17
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources).	17

Section and Topic	Item #	Checklist item	Location where item is reported
		Describe any assumptions made about any missing or unclear information.	
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	18
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	18-19
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	18
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	17-18
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	19
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	19
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	n/a
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n/a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	19
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	19
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	20-21
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	22
Study characteristics	17	Cite each included study and present its characteristics.	22-29
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	30 / 36
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	31-35
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	37-38
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its	n/a

Section and Topic	Item #	Checklist item	Location where item is reported
		precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n/a
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n/a
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n/a
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n/a
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	39
	23b	Discuss any limitations of the evidence included in the review.	40
	23c	Discuss any limitations of the review processes used.	41
	23d	Discuss implications of the results for practice, policy, and future research.	41
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Appendix 1.2
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Appendix 1.2
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Appendix 1.2
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	9
Competing interests	26	Declare any competing interests of review authors.	9
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix 1.7

Appendix 1.1 Synthesis Without Meta-analysis (SWiM) Reporting Checklist

SWiM is intended to complement and be used as an extension to the PRISMA 2020 Reporting Checklist			
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
Methods			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	19	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	n/a	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	18	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	19	
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	19	

SWiM reporting item	Item description	Page in manuscript where item is reported	Other*
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	n/a	
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings	19	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	19	
Results			
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	37-38	
Discussion			
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question	40	

Appendix 1.2 Systematic Review Protocol & Amendments

A protocol for this review was registered on Prospero on 09/08/2025, with record number: CRD420251082375, available at: https://www.crd.york.ac.uk/PROSPERO/view/CRD420251082375

There were several amendments to this protocol. Most notably, the scope was refined from reviewing the efficacy of problem-solving interventions for problem-solving outcomes, to problem-solving interventions that include a solution-generation component on outcomes that also include an assessment of solution generation. This was primarily because the solution generation stage is the target of the Major Research Project, Chapter 2 of this volume.

Eligibility criteria were further refined to include only interventions that explicitly trained solution generation (amongst other intervention components) owing to heterogeneity in outcome measures, and since solution generation interventions were often embedded in broader cognitive interventions.

Additionally, self-report subjective measures were initially included, but were later excluded after it transpired many subjective measures of PS do not include items that assess solution generation, and given insight problems in this population which may have resulted in inaccurate or misleading results.

Appendix 1.3 Systematic Review Database & Trial Register Search Strategies

Databases

Embase

Date of search: 25/08/2025
Interface name: Ovid
Dates of coverage: 1947-2025
URL:https://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=4g8HTLZmn6lJXM16Ytxy5hQkRCnzpq1SpYsmfls9HuVU7ywmZfnMqCu41a9kJPo8E

1	exp problem solving/	49694
2	decision making/	323974
3	("problem solving" or "problem-solving").ti,ab,kw.	32531
4	or/1-3	380402
5	cognition/	385816
6	executive function/	68364
7	exp cognitive defect/	732611
8	((executive function* or cognit*) adj5 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ti,ab,kw.	258080
9	((organi* or manag*) adj5 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ti,ab,kw.	144294
10	or/5-9	1217591
11	4 or 10	1560841
12	exp head injury/	422790
13	brain edema/	46684
14	exp brain injury assessment/	57085
15	exp unconsciousness/	123766
16	exp traumatic brain injury/	81954
17	pneumocephalus/	3933
18	exp traumatic epilepsy/	2681
19	((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran*) adj4 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)).ti,ab,kw.	408300
20	((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran*) adj4 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)).ti,ab,kw.	135618
21	((Glasgow adj2 ((coma or outcome) adj2 (scale* or score*))) or "rancho los amigos scale").ti,ab,kw.	30047
22	diffuse axonal injur*.ti,ab,kw.	2442
23	((brain or cerebral or intracranial) adj4 (oedema or edema or swell*)).ti,ab,kw.	33930
24	((unconscious* or coma* or concuss*) adj4 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)).ti,ab,kw.	14517
25	exp brain hemorrhage/	214537

26 (coma adj5 (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*)).ti,ab,kw. 8173
27 exp brain injury/ 257831
28 or/12-27 976073
29 rehabilitation/ 142112
30 cognitive remediation therapy/ 2477
31 (rehabilit* or remediat* or training or neurorehabilitation or therapy or metacognit*).ti,ab,kw. 5049901
32 or/29-31 5075505
33 exp self help device/ 4413
34 computer/ 109009
35 exp general software/ 442160
36 (external and (aid or system*)).ti,ab,kw. 139725
37 ("cognitive aid" or ipad* or tablet* or iphone* or "personal data assistant*" or "PDA").ti,ab,kw. 170274
38 ((technical or technological or technology) adj4 (aid or assist*)).ti,ab,kw. 30512
39 ((technical or technological or technology) adj4 (app or application*)).ti,ab,kw. 32549
40 ("voice recorder*" or (answer* and (system* or service*))).ti,ab,kw. 68580
41 (((smart or cell* or mobile) adj2 (phone* or telephone*)) or cellphone).ti,ab,kw. 29393
42 ((technical or technological or technology) adj4 (aid or assist*)).ti,ab,kw. 30512
43 ((electronic or assistive) adj4 (organiser* or device*)).ti,ab,kw. 32621
44 ("virtual reality" or "virtual-reality" or "VR" or "computer-based" or "interactive training" or "computer assisted").ti,ab,kw. 104100
45 (online or web-based or internet or telehealth or telemedicine or e-health).ti,ab,kw. 577763
46 or/33-45 1629357
47 32 or 46 6416006
48 11 and 28 and 47 21189
49 11 and 28 and 46 4724
50 cognitive remediation therapy/ 2477
51 (((neuro* or cognit*) adj6 (rehabilit* or remediat* or training or therapy)) or neurorehabilit* or metacognit*).ti,ab,kw. 167890
52 50 or 51 168441
53 46 or 52 1776834
54 11 and 28 and 53 9713
55 Clinical Trial/ 1656741
56 Randomized Controlled Trial/1094747
57 controlled clinical trial/ 460277
58 multicenter study/ 509447
59 Phase 3 clinical trial/ 113573
60 Phase 4 clinical trial/ 15843
61 exp RANDOMIZATION/ 101796
62 Single Blind Procedure/ 81631
63 Double Blind Procedure/ 309272
64 Crossover Procedure/ 104354
65 PLACEBO/ 512892
66 randomi?ed controlled trial$.tw. 431637

67 rct.tw. 75244
68 (random$ adj2 allocat$).tw. 70358
69 single blind$.tw. 44840
70 double blind$.tw. 329871
71 ((treble or triple) adj blind$).tw. 3204
72 placebo$.tw. 469361
73 Prospective Study/ 1001573
74 or/55-73 3826390
75 Case Study/ 118734
76 case report.tw. 656433
77 abstract report/ or letter/ 1391317
78 Conference proceeding.pt. 0
79 Editorial.pt. 843706
80 Letter.pt. 1371244
81 Note.pt. 1015781
82 or/75-81 4090610
83 74 not 82 3672058
84 83 not (exp animal/ not exp human/) 3576520
85 limit 84 to english language 3400347
86 54 and 85 2448
87 (randomized adj2 trial).ti,ab. 384824
88 (87 or 74) not 82 3703083
89 88 not (exp animal/ not exp human/) 3606936
90 limit 89 to english language 3429896
91 54 and 90 2463

CINAHL
Date of search - 26/10/2025
Interface name - EBSCO Host
Dates of coverage: 1953-2025

#	Query	Limiters/Expanders	Last Run Via	Results
S61	S44 and S60	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,284
S60	S56 or S59	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,919,715
S59	XB (random* N2 trial OR clinical trial OR controlled trial OR "pilot trial" OR "feasibility trial" OR "pilot study" OR "feasibility study" OR "pilot randomized" OR "feasibility randomized" OR "pilot randomised" OR "feasibility randomised" OR "exploratory trial" OR "preliminary trial")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	410,356
S58	S44 and S56	Expanders - Apply equivalent subjects Narrow by Language: - english Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,197
S57	S44 and S56	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,211
S56	S45 or S46 or S47 or S48 or S49 or S50 or	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	1,859,376

	S51 or S52 or S53 or S54 or S55	Search modes - Proximity	Search Screen - Advanced Search Database - CINAHL	
S55	TX allocat* random*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	17,246
S54	(MH "Quantitative Studies")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	45,418
S53	(MH "Placebos")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	14,538
S52	TX placebo*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	83,221
S51	TX random* allocat*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	17,246
S50	(MH "Random Assignment")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	96,089
S49	TX randomi* control* trial*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	292,520
S48	(TX ((singl* n1 blind*) or (singl* n1 mask*))) OR (or TX ((doubl* n1 blind*) or (doubl* n1 mask*)))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced	1,369,432

	OR (TX ((tripl* n1 blind*) or (tripl* n1 mask*))) OR (TX ((trebl* n1 blind*) or (trebl* n1 mask*)))		Search Database - CINAHL	
S47	TX clinic* n1 trial*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	356,581
S46	PT Clinical trial	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	116,269
S45	(MH "Clinical Trials+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	369,771
S44	S11 and S25 and S43	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	4,150
S43	S30 or S42	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,820,420
S42	S31 or S32 or S33 or S34 or S35 or S36 or S37 or S38 or S39 or S40 or S41	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	839,128
S41	XB (online or web-based or internet or telehealth or telemedicine or e-health)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	179,421
S40	XB ("virtual reality" or "virtual-reality" or VR or computer-based or	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases Search Screen - Advanced	21,466

	"interactive training" or "computer assisted")	Search modes - Proximity	Search Database - CINAHL	
S39	XB ((electronic or assistive) N4 (organiser* or device*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	6,215
S38	XB (((smart or cell* or mobile) N2 (phone* or telephone*)) or cellphone)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	7,723
S37	XB ("voice record*" or (answer* and (system* or service*)))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	13,337
S36	XB ((technical or technolog*) N4 (app or application*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	5,375
S35	XB ((technical or technolog*) N4 (aid or assist*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	11,942
S34	XB ("cognitive aid" or ipad* or tablet* or iphone* or "personal data assistant*" or PDA)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	16,990
S33	XB (external and (aid or system*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	14,828
S32	(MH "Computer Systems+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	583,382

S31	(MH "Assistive Technology Devices+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	40,936
S30	S26 or S27 or S28 or S29	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,145,654
S29	XB (((neuro* or cognit*) N6 (rehabilit* or remediat* or training or therapy)) or neurorehabilit* or metacognit*)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	43,953
S28	XB (rehabilit* or remediat* or training or neurorehabilitation or therapy or metacognit*)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	912,442
S27	(MH "Cognitive Remediation")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	220
S26	(MH "Rehabilitation+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	360,123
S25	S11 and S24	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	9,544
S24	S12 or S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20 or S21 or S22 or S23	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	113,217

S23	XB (coma N5 (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	2,015
S22	XB ((unconscious* or coma* or concuss*) N4 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	3,939
S21	XB ((brain or cerebral or intracranial) N4 (oedema or edema or swell*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	3,015
S20	XB "diffuse axonal injur*"	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	274
S19	XB ((Glasgow N2 ((coma or outcome) N2 (scale* or score*))) or "rancho los amigos scale")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	6,348
S18	XB ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra#cran* or inter#cran*) N4 (haematoma* or hematoma* or haemorrhag* or	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	17,771

	hemorrhag* or bleed* or pressur*))			
S17	XB ((head OR crani* OR cerebr* OR capitis OR brain* OR forebrain* OR skull* OR hemispher* OR intra#cran* OR inter#cran*) N4 (injur* OR trauma* OR damag* OR lesion* OR wound* OR destruction* OR oedema* OR edema* OR contusion* OR concus* OR fracture*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	64,999
S16	(MH "Unconsciousness+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	10,512
S15	(MH "Hypoxia, Brain+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	2,734
S14	(MH "Brain Injuries+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	35,655
S13	(MH "Cerebral Edema+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	2,309
S12	(MH "Head Injuries+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	50,270
S11	S4 or S10	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced	263,984

			Search Database - CINAHL	
S10	S5 or S6 or S7 or S8 or S9	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	184,303
S9	XB ((organi* or manag*) N5 (disorder* or dysfunction* or impair* or difficult* or problem* or disab*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	36,656
S8	XB (("executive function*" OR cognit*) N5 (disorder* OR dysfunction OR impair* OR difficult* OR problem* OR disability))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	61,716
S7	(MH "Cognition Disorders+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	42,344
S6	(MH "executive function")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	8,374
S5	(MH Cognition)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	77,945
S4	S1 or S2 or S3	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	86,221
S3	XB ("problem solving" or "problem-solving")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced	11,680

			Search Database - CINAHL	
S2	(MH “Decision Making”)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	65,521
S1	(MH "Problem Solving+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	14,826

Medline
Date of search - 30/10/2025
Interface name – EBSCO Host
Dates of coverage: 1949 - 2025

#	Query	Limiters/Expanders	Last Run Via	Results
S72	S44 and S71	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,321
S71	S69 or S70	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	2,525,846
S70	XB (random* N2 trial OR clinical trial OR controlled trial OR "pilot trial" OR "feasibility trial" OR "pilot study" OR "feasibility study" OR "pilot randomized" OR "feasibility randomized" OR "pilot randomised" OR "feasibility randomised" OR "exploratory trial" OR "preliminary trial")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,202,064
S69	S64 not S68	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	2,193,087
S68	S65 or S66 or S67	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,684,653

S67	PT Historical Article	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	375,519
S66	PT Letter	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,313,666
S65	PT Case Study	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	230,288
S64	S56 or S63	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	2,233,780
S63	S57 or S58 or S59 or S60 or S61 or S62	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,801,995
S62	TX (allocat* N2 random*)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	158,591
S61	TX Randomly Allocated	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	45,800
S60	TX Placebo*	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search	349,723

			Database - MEDLINE	
S59	(MH "Placebos")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	36,149
S58	TX ((singl* OR doubl* OR treb* OR tripl*) N1 (blind* OR mask*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	366,594
S57	TX (clinical N1 trial*)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,459,013
S56	S45 OR S46 OR S47 OR S48 OR S49 OR S50 OR S51 OR S52 OR S53 OR S54 OR S55	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,378,863
S55	PT Multicenter Study	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	381,974
S54	PT controlled clinical trial	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	95,743
S53	PT Clinical Trial, Phase IV	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	2,863
S52	PT Clinical Trial, Phase III	Expanders - Apply equivalent subjects Search modes -	Interface - EBSCOhost Research Databases Search Screen - Advanced	25,610

		Proximity	Search Database - MEDLINE	
S51	PT clinical trial, phase ii	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	44,709
S50	PT clinical trial, phase i	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	28,169
S49	PT Clinical Trial	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	537,549
S48	(MH "Single-Blind Method")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	35,669
S47	(MH "Double-Blind Method")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	186,417
S46	(MH "Random Allocation")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	108,963
S45	PT randomized controlled trial	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	648,343
S44	S11 and S25 and S43	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	6,878

		Search modes - Proximity	Search Screen - Advanced Search Database - MEDLINE	
S43	S30 or S42	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	4,649,209
S42	S31 or S32 or S33 or S34 or S35 or S36 or S37 or S38 or S39 or S40 or S41	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	998,557
S41	XB (online or web-based or internet or telehealth or telemedicine or e-health)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	437,776
S40	XB ("virtual reality" or "virtual-reality" or VR or computer-based or "interactive training" or "computer assisted")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	75,642
S39	XB ((electronic or assistive) N4 (organiser* or device*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	31,614
S38	XB (((smart or cell* or mobile) N2 (phone* or telephone*)) or cellphone)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	20,662
S37	XB ("voice record*" or (answer* and (system* or service*)))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	40,328

S36	XB ((technical or technolog*) N4 (app or application*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	48,103
S35	XB ((technical or technolog*) N4 (aid or assist*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	31,838
S34	XB ("cognitive aid" or ipad* or tablet* or iphone* or "personal data assistant*" or PDA)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	91,281
S33	XB (external and (aid or system*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	108,119
S32	(MH "Computer Systems+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	220,691
S31	(MH "Self-Help Devices")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	6,352
S30	S26 or S27 or S28 or S29	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	3,812,082
S29	XB (((neuro* or cognit*) N6 (rehabilit* or remediat* or training or therapy)) or	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search	126,459

	neurorehabilit* or metacognit*)		Database - MEDLINE	
S28	XB (rehabilit* or remediat* or training or neurorehabilitation or therapy or metacognit*)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	3,582,147
S27	(MH "Cognitive Remediation")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	719
S26	(MH "Rehabilitation+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	385,729
S25	S11 and S24	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	27,982
S24	S12 or S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20 or S21 or S22 or S23	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	519,821
S23	XB (coma N5 (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	6,735

S22	XB ((unconscious* or coma* or concuss*) N4 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	11,178
S21	XB ((brain or cerebral or intracranial) N4 (oedema or edema or swell*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	22,820
S20	XB "diffuse axonal injur*"	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,486
S19	XB ((Glasgow N2 ((coma or outcome) N2 (scale* or score*))) or "rancho los amigos scale")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	21,198
S18	XB ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra#cran* or inter#cran*) N4 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	94,006
S17	XB ((head OR crani* OR cerebr* OR capitis OR brain* OR forebrain* OR skull* OR hemispher* OR intra#cran* OR	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	293,680

	inter#cran*) N4 (injur* OR trauma* OR damag* OR lesion* OR wound* OR destruction* OR oedema* OR edema* OR contusion* OR concus* OR fracture*))			
S16	(MH "Unconsciousness+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	46,117
S15	(MH "Hypoxia, Brain+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	15,209
S14	(MH "Brain Injuries+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	90,097
S13	(MH "Brain Edema+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	16,019
S12	(MH "Craniocerebral Trauma+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	190,698
S11	S4 or S10	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	632,804
S10	S5 or S6 or S7 or S8 or S9	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	489,809

S9	XB ((organi* or manag*) N5 (disorder* or dysfunction* or impair* or difficult* or problem* or disab*))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	117,869
S8	XB (("executive function*" OR cognit*) N5 (disorder* OR dysfunction OR impair* OR difficult* OR problem* OR disability))	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	198,990
S7	(MH "Cognition Disorders+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	132,084
S6	(MH "executive function")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	22,966
S5	(MH Cognition)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	144,047
S4	S1 or S2 or S3	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	157,438
S3	XB ("problem solving" or "problem-solving")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	24,653

S2	(MH “Decision Making”)	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	111,491
S1	(MH "Problem Solving+")	Expanders - Apply equivalent subjects Search modes - Proximity	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	31,649

CENTRAL
Date of search - 02/11/2025
Interface name – Cochrane Library Web Interface
Dates of coverage: n/a
URL: https://www.cochranelibrary.com/advanced-search/search-manager

ID	Search	Hits
#1	MeSH descriptor: [Problem Solving] explode all trees	2096
#2	MeSH descriptor: [Decision Making] this term only	3535
#3	("problem solving" or "problem-solving"):ti,ab,kw	7587
#4	{or #1-#3}	11204
#5	MeSH descriptor: [Cognition] this term only	12958
#6	MeSH descriptor: [Executive Function] this term only	1995
#7	MeSH descriptor: [Cognitive Dysfunction] this term only	4781
#8	((executive NEXT function* OR cognit*) near/5 (disorder* OR dysfunction OR impair* OR difficult* OR problem* OR disability)):ti,ab,kw	34309
#9	((organi* or manag*) near/5 (disorder* or dysfunction* or impair* or difficult* or problem* or disab*)):ti,ab,kw	10246
#10	{or #5-#9}	53760
#11	#4 or #10	62649
#12	MeSH descriptor: [Craniocerebral Trauma] explode all trees	5790
#13	MeSH descriptor: [Brain Edema] this term only	285
#14	MeSH descriptor: [Brain Injuries] explode all trees	3930
#15	MeSH descriptor: [Hypoxia, Brain] explode all trees	510
#16	MeSH descriptor: [Unconsciousness] explode all trees	1326
#17	MeSH descriptor: [Intracranial Hemorrhages] explode all trees	3305
#18	((head OR crani* OR cerebr* OR capitis OR brain* OR forebrain* OR skull* OR hemispher* OR intra#cran* OR inter#cran*) near/4 (injur* OR trauma* OR damag* OR lesion* OR wound* OR destruction* OR oedema* OR edema* OR contusion* OR concus* OR fracture*)):ti,ab,kw	18719
#19	((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra#cran* or inter#cran*) near/4 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)):ti,ab,kw	14367
#20	((Glasgow near/2 ((coma or outcome) near/2 (scale* or score*))) or "rancho los amigos scale"):ti,ab,kw	3948
#21	diffuse axonal NEXT injur*:ti,ab,kw	92
#22	((brain or cerebral or intracranial) near/4 (oedema or edema or swell*)):ti,ab,kw	1387
#23	((unconscious* or coma* or concuss*) near/4 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)):ti,ab,kw	1157
#24	(coma near/5 (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*)):ti,ab,kw	895
#25	{or #12-#24}	36123
#26	#11 and #25	2809
#27	MeSH descriptor: [Rehabilitation] this term only	403
#28	MeSH descriptor: [Telerehabilitation] explode all trees	469
#29	MeSH descriptor: [Neurological Rehabilitation] explode all trees	4895
#30	MeSH descriptor: [Cognitive Remediation] this term only	341
#31	(rehabilit* or remediat* or training or neurorehabilitation or therapy or metacognit*):ti,ab,kw	1067502

#32 (((neuro* or cognit*) N6 (rehabilit* or remediat* or training or therapy)) or neurorehabilit* or metacognit*):ti,ab,kw 2957
#33 {or #27-#32} 1067518
#34 MeSH descriptor: [Self-Help Devices] explode all trees 591
#35 MeSH descriptor: [Computer Systems] explode all trees 10249
#36 MeSH descriptor: [Software] explode all trees 7028
#37 (external and (aid or system*)):ti,ab,kw 6028
#38 ("cognitive aid" or ipad* or tablet* or iphone* or personal data NEXT assistant* or PDA):ti,ab,kw 66860
#39 ((technical or technolog*) near/4 (aid or assist*)):ti,ab,kw 2922
#40 ((technical or technolog*) near/4 (app or application*)):ti,ab,kw 987
#41 (voice NEXT record* or (answer* and (system* or service*))):ti,ab,kw 6880
#42 (((smart or cell* or mobile) near/2 (phone* or telephone*)) or cellphone):ti,ab,kw 8038
#43 ((electronic or assistive) near/4 (organiser* or device*)):ti,ab,kw 3104
#44 ("virtual reality" or "virtual-reality" or VR or computer-based or "interactive training" or "computer assisted"):ti,ab,kw 35329
#45 (online or web-based or internet or telehealth or telemedicine or e-health):ti,ab,kw 60135
#46 {or #34-#45} 183050
#47 #33 or #46 1162465
#48 #11 and #26 and #47 1963

Trial Registers

Clinicaltrials.gov
Date of search – 07/11/25
Interface name – Clinicaltrials.gov - basic search
Dates of coverage: n/a
URL: https://clinicaltrials.gov/

Condition/disease
(Traumatic Brain Injury OR "traumatic brain injury" OR TBI Traumatic Brain Injury OR TBI OR Acquired Brain Injury OR Acquired Brain Injuries OR Acquired Brain Injury Including Stroke OR "acquired head injury" OR “acquired brain injury” OR Head Trauma OR Head Trauma Injury OR "head trauma" OR Brain Injury OR Craniocerebral Trauma OR Brain Trauma OR "brain injury" OR "head injury" OR brain lesions OR "brain lesion" OR Brain Hemorrhage OR "brain hemorrhage" OR "cerebral hemorrhage" OR Diffuse Axonal Injury OR Brain Edema OR "brain oedema" OR Concussion, Brain OR Coma OR Unconsciousness)

Other terms
(Cognitive Rehabilitation OR "cognitive rehabilitation" OR Cognitive Remediation OR "cognitive remediation" OR Cognitive Training OR "cognitive training" OR Neurorehabilitation OR "neurorehabilitation" OR Problem Solving OR "problem solving" OR "problem-solving" OR Executive Function OR "executive function" OR Executive Dysfunction OR "executive dysfunction" OR Cognitive Impairment OR Cognitive Disability)

= 1,513 papers

Filter: completed = 667 papers

WHO ICTRP
Date of search – 07/11/25
Interface name - WHO ICTRP Search Portal – basic search
Dates of coverage: n/a
URL: https://trialsearch.who.int/

(problem solv* OR problem-solv* OR executive function* OR cognitive impair* OR cognitive disabil* OR cognitive disorder*)
AND
(traumatic brain injur* OR TBI OR acquired brain injur* OR head trauma* OR brain injur* OR brain lesion* OR brain hemorrhage* OR diffuse axonal injur* OR brain edema* OR brain oedema OR coma OR concussion)
AND
(rehabilitation* OR cognitive rehabilitation* OR cognitive remediation* OR cognitive training* OR neurorehabilitation* OR assistive technolog* OR cognitive aid* OR self-help device* OR smartphone* OR tablet* OR mobile application* OR virtual reality*)

=139 results for 137 trials

Appendix 1.4 Systematic Review Hand Searches

All searched online on 23.12.25

The Journal of Head Trauma Rehabilitation
Volume 40(6) pgs. 395-478,E482-E543 November/December 2025
Volume 40(5) pgs. 309-393,E340-E481 September/October 2025
Volume 40(4) pgs. 221-307,E272-E339 July/August 2025

Neurorehabilitation and Neural Repair
Volume 39 Issue 12, December 2025
Volume 39 Issue 11, November 2025
Volume 39 Issue 10, October 2025

Applied Neuropsychology (Adult)
Applied Neuropsychology: Adult, Volume 32, Issue 6 (2025)
Applied Neuropsychology: Adult, Volume 32, Issue 5 (2025)
Applied Neuropsychology: Adult, Volume 32, Issue 4 (2025)

Applied Neuropsychology (Child)
Applied Neuropsychology: Child, Volume 14, Issue 4 (2025)
Applied Neuropsychology: Child, Volume 14, Issue 3 (2025)
Applied Neuropsychology: Child, Volume 14, Issue 2 (2025)

International Journal of Rehabilitation Research
Volume 48(4) pgs. 199-243 December 2025
Volume 48(3) pgs. 135-198 September 2025
Volume 48(2) pgs. 83-134 June 2025

Brain Injury
Brain Injury, Volume 39, Issue 14 (2025)
Brain Injury, Volume 39, Issue 13 (2025)
Brain Injury, Volume 39, Issue 12 (2025)

Neuropsychological Rehabilitation
Neuropsychological Rehabilitation, Volume 35, Issue 10 (2025)
Neuropsychological Rehabilitation, Volume 35, Issue 9 (2025)
Neuropsychological Rehabilitation, Volume 35, Issue 8 (2025)

Disability and Rehabilitation
Disability and Rehabilitation, Volume 47, Issue 26 (2025)
Disability and Rehabilitation, Volume 47, Issue 25 (2025)
Disability and Rehabilitation, Volume 47, Issue 24 (2025)

0 additional papers identified across all hand searches

Source paper	Potential papers & reason for non-inclusion	New papers
Cisneros et al. (2021)	(Von Cramon et al., 1991) - not an RCT	0
Eliav et al. (2024)*		0
Fong & Howie (2009)	(Cicerone & Giacino, 1992) – not an RCT (Fong, 2003) - dissertation manuscript. Published article already included.	0
Jacoby et al. (2013)*	(Sweeney et al., 2010) - not an RCT	0
Jak et al. (2019)		0
Man et al. (2013)*	(Poon et al., 2007) – sample includes children	0
Miotto et al. (2009)	(Foxx et al., 1989) – not an RCT	0
Novakovic et al. (2018)*		0
Novakovic et al. (2021)*	(D'Zurilla & Goldfried, 1971) - not an RCT	0
Ownsworth et al. (2017)*		0
Rath et al. (2003)		0
Spikman et al. (2010)		0
Twamley (2014)		0
Twamley (2015)		0

Table 3.1 Backward Reference List Checking

* Previously included papers

Appendix 1.5 Characteristics of Excluded Borderline Studies

Study	Reason for exclusion
(Cantor et al., 2014)	Composite EF measure used (BADS score), no isolation of solution-generation outcome.
(Eliav et al., 2024)	Solution generation was embedded variably within functional tasks but not delivered as a discrete, standardized component.
(Hewitt et al., 2006)	Includes participants under 18 years old.
(Jacoby et al., 2013)	All participants received training, which includes sub-goaling and sequencing, but no explicit solution-generation training.
(Levine et al., 2011)	GMT intervention. Includes sub-goaling, but not explicit solution generation training.
(Liu et al., 2022)	Broader EF intervention, no explicit solution-generation training.
(Man et al., 2006)	No validated outcome measure.
(Man et al., 2013)	Includes embedded PS but limited to selecting correct responses trained using feedback
(Ownsworth et al., 2017)	Includes constrained strategy generation in response to errors (reactive), but no proactive/explicit solution generation training.
(Novakovic-Agopian et al., 2018; 2021)	GMT and attentional type intervention. Sub-goaling present, but no explicit solution-generation trained.
(Tornås et al., 2016)	GMT intervention. Includes sub-goaling, but no solution-generation training.
(Von Cramon et al., 1991)	Not an RCT. Participants allocated in sequence of admission.

Table 3.2 Characteristics of Borderline Studies

Appendix 1.6 Outcome Measure Selection Rationale

Study	Relevant outcome measures	Subscales reported	Subscale most closely assessing solution generation	Rationale
Cisneros et al. (2021)	1. BADS Six Elements Test Adapted (SET-A)	1. Tackling 6 sub-tasks, inter-task balance, checking time, avoiding rule breaking, efficient behaviour, total score, total number of points	1. Tackling 6 sub-tasks	1. Most closely aligned with solution generation
	2. DKEFS Sorting Test	2. Confirmed correct sort, free sorting description, time-per-sort ratio	2. Confirmed correct sort	2. Most closely aligned with solution generation
Fong & Howie (2009)	1. Means-ends Problem Solving (MEPS)	1. Means, Ratio	1. Means	1. A measure of solution generation.
	2. Social Problem-Solving Video Measure (SPSVM)	2. Nature, planning, representation, monitoring, total average	2. Planning	2. Most closely aligned with solution generation
	3. BADS Modified Six Elements Test (MSE)	3. Profile score	3. Profile score	3. Only subscale reported
	4. BADS Key Search (KS)	4. Profile score	4. Profile score	4. Only subscale reported
	5. Raven's Progressive Matrices (RPM)	5. Profile score	5. Profile score	5. Only subscale reported

Jak et al. (2019)	1. Wisconsin Card Sorting Test-64 card version (WCST-64)	1. Total errors score	1. Total errors score	1. Only subscale reported
Miotto et al. (2009)	1. Modified Multiple Errands Task (MMET) 2. WCST 3. Virtual Planning Test (VIP)	1. Activities undertaken (minus errors) 2. Categories 3. Total score	1. Activities undertaken (minus errors) 2. Categories 3. Total score	1. Only subscale reported 2. Only subscale reported 3. Only subscale reported
Rath et al. (2003)	1. Problem Solving Roleplay Test (PSRPT) 2. WCST	1. Total score 2. Perseverative response score	1. Total score 2. Perseverative response score	1. Only subscale reported 2. Only subscale reported
Spikman et al. (2010)	1. Tower of London (TOL) 2. Executive Secretarial Task (EST)	1. Number correct 2. Initiative, prospective, executive	1. Number correct 2. Executive	1. Only subscale reported 2. Most closely aligned with solution generation
Twamley et al. (2014)	1. WCST-64	1. Perseverative errors	1. Perseverative errors	1. Most closely aligned with solution generation
Twamley et al. (2015)	1. WCST-64	1. Perseverative errors	1. Perseverative errors	1. Most closely aligned with solution generation

Table 3.3

Outcome Measure Selection Rationale

Appendix 1.7 Effect Size Calculations

NEUROPSYCHS POST

Study	Year	Outcome measure	Subscale	Type	Intervention N	Intervention M	Intervention SD	Control N	Control M	Control SD	g	CI	Method	Notes
Cisneros	2021	SET-A	Tackling 6 sub-tests	Between post effects	20	2.45	0.89	11	1.91	1.22	0.51	[-0.21, 1.25]	M,SD	
Cisneros	2021	Sorting Test	Confirmed Correct Sort	Between post effects	20	8.1	2.97	10	5.91	2.55	0.75	[-0.01, 1.51]	M,SD	
Fong & Howie	2009	MEPSM	Means	Between change scores	16	3.3	5.4	17	0.7	3.6	0.56	[-0.12, 1.24]	M,SD	
Fong & Howie	2009	SPSVM	Planning	Between change scores	16	0.7	2.1	17	0.1	1.1	0.35	[-0.32, 1.02]	M,SD	
Fong & Howie	2009	MSE	Profile	Between change scores	16	1.5	1.5	17	0.7	1.2	0.58	[-0.10, 1.26]	M,SD	
Fong & Howie	2009	KS	Profile	Between change scores	16	3.9	3	17	2.8	4	0.3	[-0.37, 0.97]	M,SD	
Fong & Howie	2009	RPM	Profile	Between change scores	16	5.2	7.3	17	6.2	6.8	-0.14	[-0.81, 0.53]	M,SD	
Jak	2019	WCST-64	Total errors	Between post effects	26	53.36	6.71	23	46.91	10.44	-0.73	[-1.30, -0.16]	M,SD	g and CI direction flipped
Miotto	2009	WCST	Categories	Between change scores*	10	1	0.79	20	1	0.83	0	[-0.16, 0.86]	M,SD	*Control groups combined, change score g calculated, raw SDs used as proxy as no change SDs reported
Rath	2003	WCST	Perseverative responses	Within group change	25	NR	NR	28	NR	NR	0.35	[-0.16, 0.86]	d -> g (& N tot)	Within group, g and CI direction not flipped as converted from d
Spikman	2010	TOL	Number correct	Between post effects	38	10.9	1.6	37	11.3	0.9	-0.3	[-0.75, 0.15]	M,SD	
Twamley (2014)	2014	WCST	Perseverative errorrs	Between post effects	16	-0.1	4.9	18	1.9	8	0.29	[-0.37, 0.95]	M, SD	g and CI direction flipped

NEUROPSYCHS FOLLOW UP

Study	Year	Outcome measure	Subscale	Type	Intervention N	Intervention M	Intervention SD	Control N	Control M	Control SD	g	CI	Method	Notes
Cisneros	2021	SET-A	Tackling 6 sub-tests	Between post effects	17	2.24	1.03	7	2	1.29	0.21	[-0.67, 1.09]	M,SD	
Cisneros	2021	Sorting Test	Confirmed Correct Sort	Between post effects	17	8.82	1.98	7	6.86	2.79	0.85	[-0.06, 1.77]	M,SD	
Fong & Howie	2009	MSE	Profile	Between change scores	16*	-1.1	1.8	17*	0.5	0.5	-1.2	[-1.93, -0.46]	M,SD	*Ns not provided at follow up, baseline Ns imputed
Fong & Howie	2009	KS	Profile	Between change scores	16*	-2.1	2.3	17*	0.1	3.3	-0.75	[-1.46, -0.04]	M,SD	*Ns not provided at follow up, baseline Ns imputed
Fong & Howie	2009	RPM	Profile	Between change scores	16*	1.7	5.1	17*	1.2	3.4	0.11	[-0.57, 0.80]	M,SD	*Ns not provided at follow up, baseline Ns imputed
Jak	2019	WCST-64	Total errors	Between post effects	20	54.85	8.11	15	50.47	9.99	-0.48	[-1.16, 0.20]	M,SD	g and CI direction flipped
Miotto	2009	WCST	Categories	Between change scores*	N/A	N/A	N/A	N/A	N/A	N/A				Due to crossover design, all groups had received intervention at follow-up, making between group comparison meaningless
Rath	2003	WCST	Perseverative responses	Within group change	18	NR	NR	13	NR	NR				Insufficient information reported to calculate
Spikman	2010	TOL	Number correct	Between post effects	35	11	1.4	36	11	1.1	0	[-0.45, 0.47]	M,SD	
Twamley (2015)	2015	WCST	Perseverative errorrs	Between post effects	25	NR	NR	25	NR	NR	-0.58	[-1.15, -0.01]	d -> g (& N tot)	g and CI direction not flipped as converted from d

FUNCTIONAL MEASURES POST

Study	Year	Outcome measure	Subscale	Type	Intervention N	Intervention M	Intervention SD	Control N	Control M	Control SD	g	CI	Method	Notes
Miotto	2009	MMET	Activities undertaken	Between change scores*	10	1	0.92	20	0	1.29	0.82	[0.05, 1.59]	M,SD	*Control groups combined, change score g calculated, raw SDs used as proxy as no change SDs reported
Miotto	2009	VIP	Total score	Between change scores*	10	3	2.67	20	1.5	2.3	0.6	[-0.15, 1.36]	M,SD	*Control groups combined, change score g calculated, raw SDs used as proxy as no change SDs reported
Rath	2003	PSRPT	Total score	Within change score	32	NR	NR	28	NR	NR	0.61	[0.09, 1.13]	d -> g (& N tot)	Within group

FUNCTIONAL MEASURES FOLLOW UP

Study	Year	Outcome measure	Subscale	Type	Intervention N	Intervention M	Intervention SD	Control N	Control M	Control SD	g	CI	Method	Notes
Miotto	2009	MMET	Activities undertaken	Between change scores*	N/A	N/A	N/A	N/A	N/A	N/A				Due to crossover design, all groups had received intervention at follow-up, making between group comparison meaningless
Miotto	2009	VIP	Total score	Between change scores*	N/A	N/A	N/A	N/A	N/A	N/A				Due to crossover design, all groups had received intervention at follow-up, making between group comparison meaningless
Rath	2003	PSRPT	Total score	Within change score	18	NR	NR	13	NR	NR				Insufficient information reported to calculate
Spikman	2010	EST	Executive	Between group effects*	32	16.6	5.5	34	13.6	6.2	0.5	[0.02, 0.99]	M,SD	*Administered at follow-up only

Key

NR Not reported

N/A Reported but not usable

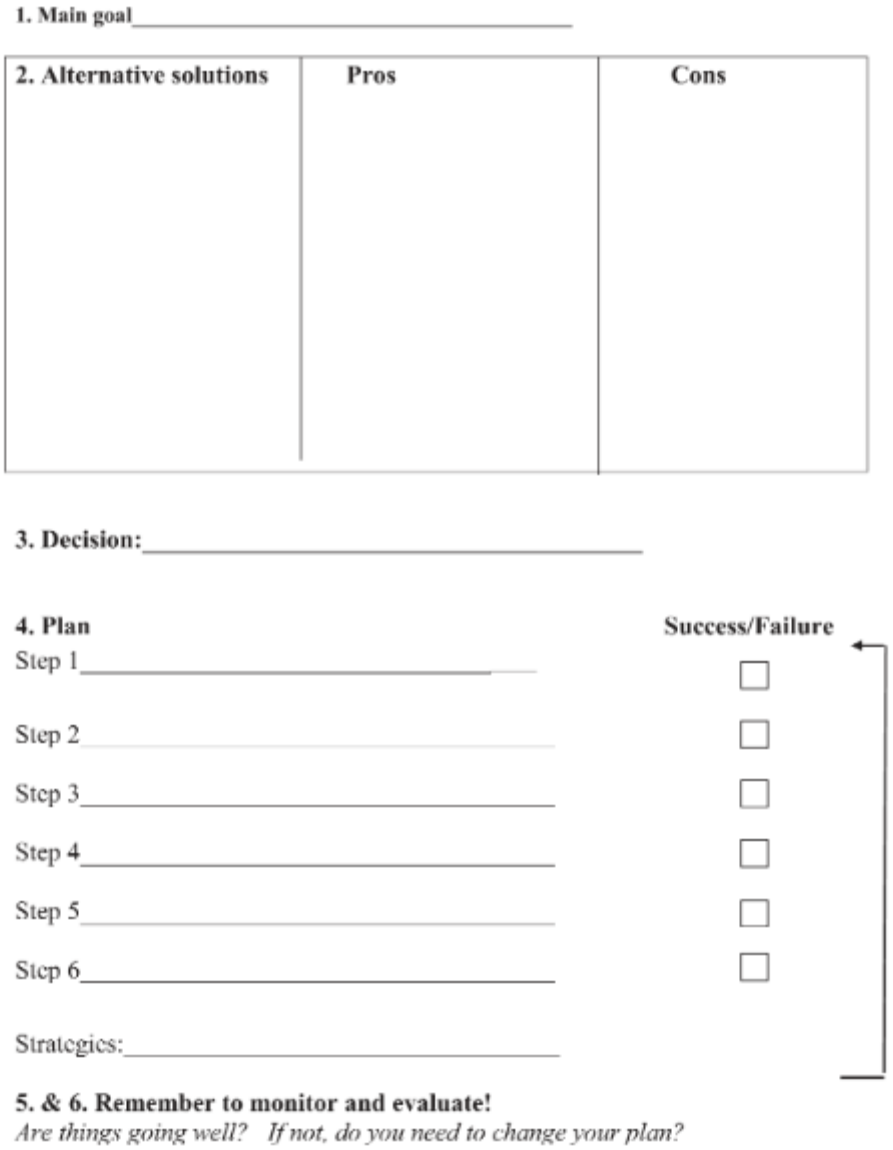
G calculated using:

Wilson, D. B. (2023). Practical meta-analysis effect size calculator (Version 2023.11.27). Url: https://www.campbellcollaboration.org/calculator/

&

https://statistics.tools/hedges-g-calculator

Appendix 1.8 Examples of Solution Generation Components of Interventions



1. Main goal_____

2. Alternative solutions	**Pros**	**Cons**

3. Decision:_____

4. Plan **Success/Failure**

Step 1_____ ☐

Step 2_____ ☐

Step 3_____ ☐

Step 4_____ ☐

Step 5_____ ☐

Step 6_____ ☐

Strategies:_____

5. & 6. Remember to monitor and evaluate!

Are things going well? If not, do you need to change your plan?

From Miotto et al. (2009)

CLEAR THINKING WORKSHEET

II. ANALYSE Precursors — I. OBSERVE Reactions *START* — III. REFRAME/PLAN

WARNING SIGNS of Reaction beginning	STOP STRATEGIES used to "STOP"	What was my initial REACTION?	ASK QUESTIONS	MAKE REVISIONS
Earliest Physical Signs Earliest Behavioural Signs Earliest Cognitive Signs Earliest Emotional Signs Signals/Alarms (How did you know that you had a problem?) —Someone else pointed it out to you? —Other people weren't acting the way you expected them to? —Your own "alarm" went off? —You knew from past experience that this type of situation is a problem? —Original plan was blocked? —Conflict between: Goals? Past/present abilities?		1A. Initial Problem Definition	1B.	1C. Revise Problem Definition
		2A. Initial Goal(s)/Subgoal(s)	2B.	2C. Revise Goal(s)/Subgoal(s)
		3A. Initial Option(s)	3B.	3C. Revised Option(s)
		+ Consequences	4B.	4C. Evaluation
		– Consequences	5B.	5C. Follow-up

From Rath et al. (2003)

Major Research Project Appendix

Appendix 2.0 CONSORT 2025 Reporting Checklist for Reporting an RCT

Section / Topic	No	CONSORT 2025 checklist item description	Reported on page no.
Title and abstract			
Title and structured abstract	1a	Identification as a randomised trial	N/A
	1b	Structured summary of the trial design, methods, results, and conclusions	55
Open science			
Trial registration	2	Name of trial registry, identifying number (with URL) and date of registration	Appendix 2.1
Protocol and statistical analysis plan	3	Where the trial protocol and statistical analysis plan can be accessed	Appendix 2.1
Data sharing	4	Where and how the individual de-identified participant data (including data dictionary), statistical code and any other materials can be accessed	Appendix 2.1
Funding and conflicts of interest	5a	Sources of funding and other support (e.g., supply of drugs), and role of funders in the design, conduct, analysis and reporting of the trial	Appendix 2.1
	5b	Financial and other conflicts of interest of the manuscript authors	Appendix 2.1
Introduction			
Background and rationale	6	Scientific background and rationale	56-59
Objectives	7	Specific objectives related to benefits and harms	60
Methods			
Patient and public involvement	8	Details of patient or public involvement in the design, conduct and reporting of the trial	61
Trial design	9	Description of trial design including type of trial (e.g., parallel group, crossover), allocation ratio, and framework (e.g., superiority, equivalence, non-inferiority, exploratory)	61
Changes to trial protocol	10	Important changes to the trial after it commenced including any outcomes or analyses that were not prespecified, with reason	61

Trial setting	11	Settings (e.g., community, hospital) and locations (e.g., countries, sites) where the trial was conducted	61
Eligibility criteria	12a	Eligibility criteria for participants	61-62
	12b	If applicable, eligibility criteria for sites and for individuals delivering the interventions (e.g., surgeons, physiotherapists)	N/A
Intervention and comparator	13	Intervention and comparator with sufficient details to allow replication. If relevant, where additional materials describing the intervention and comparator (e.g., intervention manual) can be accessed	62-63
Outcomes	14	Pre-specified primary and secondary outcomes, including the specific measurement variable (e.g., systolic blood pressure), analysis metric (e.g., change from baseline, final value, time to event), method of aggregation (e.g., median, proportion), and time point for each outcome	63
Harms	15	How harms were defined and assessed (e.g., systematically, non-systematically)	N/A
Sample size	16a	How sample size was determined, including all assumptions supporting the sample size calculation	64
	16b	Explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	17a	Who generated the random allocation sequence and the method used	64
	17b	Type of randomisation and details of any restriction (e.g., stratification, blocking and block size)	64
Allocation concealment mechanism	18	Mechanism used to implement the random allocation sequence (e.g., central computer/telephone; sequentially numbered, opaque, sealed containers), describing any steps to conceal the sequence until interventions were assigned	N/A
Implementation	19	Whether the personnel who enrolled and those who assigned participants to the interventions had access to the random allocation sequence	64
Blinding	20a	Who was blinded after assignment to interventions (e.g., participants, care providers, outcome assessors, data analysts)	65
	20b	If blinded, how blinding was achieved and description of the similarity of interventions	65
Statistical methods	21a	Statistical methods used to compare groups for primary and secondary outcomes, including harms	65-66
	21b	Definition of who is included in each analysis (e.g., all randomised participants), and in which group	65-66
	21c	How missing data were handled in the analysis	65-66
	21d	Methods for any additional analyses (e.g., subgroup and sensitivity analyses), distinguishing prespecified from post-hoc	65-66
Results			
Participant flow, including flow diagram	22a	For each group, the numbers of participants who were randomly assigned, received intended intervention, and were analysed for the primary outcome	69
	22b	For each group, losses and exclusions after randomisation, together with reasons	69

Recruitment	23a	Dates defining the periods of recruitment and follow-up for outcomes of benefits and harms	70
	23b	If relevant, why the trial ended or was stopped	70
Intervention and comparator delivery	24a	Intervention and comparator as they were actually administered (e.g., where appropriate, who delivered the intervention/comparator, how participants adhered, whether they were delivered as intended [fidelity])	70
	24b	Concomitant care received during the trial for each group	N/A
Baseline data	25	A table showing baseline demographic and clinical characteristics for each group	68
Numbers analysed, outcomes and estimation	26	For each primary and secondary outcome, by group: ● the number of participants included in the analysis ● the number of participants with available data at the outcome time point ● result for each group, and the estimated effect size and its precision (such as 95% confidence interval) ● for binary outcomes, presentation of both absolute and relative effect size	70-73
Harms	27	All harms or unintended events in each group	N/A
Ancillary analyses	28	Any other analyses performed, including subgroup and sensitivity analyses, distinguishing pre-specified from post-hoc	72-74
Discussion			
Interpretation	29	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	79-81
Limitations	30	Trial limitations, addressing sources of potential bias, imprecision, generalisability, and, if relevant, multiplicity of analyses	81-82

Appendix 2.1 Open Science Information

Registration
Name of registry: Open Science Framework
Registration number: bvr43
Created: 16/06/2025
URL: https://osf.io/bvr43

Protocol & statistical analysis plan
https://osf.io/bvr43/files/

Data sharing
Materials can be found at https://osf.io/bvr43/files/
Additional data are available upon request.

Funding information
No funding was received for this study. One participant was reimbursed for travel expenses, paid by The University of Glasgow.

Conflicts of interest
The Field Supervisor, Dr Brian O'Neill, also co-created the Smart Steps AI application, however he was excluded from all data gathering and analysis (with the exception of supervising the administration of the experiment for the first participant for training purposes).

Appendix 2.2 Project Approval Letters & Relevant Correspondence

HRA ethics approval

N.B. approval letter/correspondence has been removed from the public version due to personal data and third-party correspondence

NHS GGC Research & Innovation Approval Letter

N.B. approval letter/correspondence has been removed from the public version due to personal data and third-party correspondence

Appendix 2.3 Confirmation of Non-Substantial Amendment from Sponsor

N.B. approval letter/correspondence has been removed from the public version due to personal data and third-party correspondence

Appendix 2.4 Additional Materials

Participant Information Sheet
https://osf.io/bvr43/files/nqvkw

Consent Form
https://osf.io/bvr43/files/62sqw

Non-standard Research Materials
https://osf.io/bvr43/files/osfstorage

Experimenter Script – Training Session
https://osf.io/bvr43/files/wc5gd

Question Sets
https://osf.io/bvr43/files/nkzr9

Qualitative Data Capture Form (Interview Schedule)
https://osf.io/bvr43/files/gkucq

Detailed Analysis Plan
https://osf.io/bvr43/files/osfstorage

Data Analysis Records
https://osf.io/bvr43/files/osfstorage

Data Availability Statement
The completed dataset was used by the Principal Researcher to answer the research questions outlined. Data were stored in open-source file formats and version control was adopted. Enlighten will be used to deposit data.

Transcriptions from the Smart Steps app will be stored on the secure servers operated by WebGarden Ltd in the UK. The questions asked by participants to Smart Steps AI will not be further analyzed. Retention of transcript data previously allowed analysis (with the consent of early trial users) that served to ensure that the AI-generated responses were within acceptable parameters. The transcription is currently retained indefinitely, but WebGarden will implement a policy of removal after five years for study data.

Time will be allocated to transfer ongoing responsibility for preservation/archiving to supervisors in May 2026 alongside submission of thesis.

Appendix 2.5 Partial Approach and Consent to Contact Data

One recruitment site (CTCBI) kept detailed data on the number of participants approached and reasons for not meeting eligibility criteria. These are as follows (continued on next page):

Patients approached: 50
Excluded: 43 (reasons below)

Lack of executive functioning difficulties	14	Physical impairments precluding use of phone	2
Mental health/personality risks	5	Interpreter required	2
Not meeting severity threshold	8	Disengaged from service	2
Not interested in research	4		
Not interested in technology	2		
Work/study stress	2		
ADHD confound	2		

Service	Sept	Oct	Nov	Dec	Jan	Feb
A		Approached: 14 Consented to contact: 1 Participated: 0 Study completed: 0	Approached: 18 Consented to contact: 6 Participated: 3 Study completed: 3	Approached: 9 Consented to contact: 0 Participated: 1 Study completed: 1	Approached: 0 Consented to contact: 0 Participated: 2 Study completed: 2	Approached: ? Consented to contact: 0 Participated: 0 Study completed: 0
B	Approached: 2 Consented to contact: 2 Participated: 2 Study completed: 2	Approached: 1 Consented to contact: 1 Participated: 0 Study completed: 0	Approached: ? Consented to contact: ? Participated: 0 Study completed: 0	Approached: ? Consented to contact: 0 Participated: 0 Study completed: 0	Approached: ? Consented to contact: ? Participated: 1 Study completed: 1	Approached: 1? Consented to contact: ? Participated: 0 Study completed: 0
C			Approached: 0 Consented to contact: 0 Participated: 0 Study completed: 0	Approached: ? Consented to contact: 0 Participated: 0 Study completed: 0	Approached: 0 Consented to contact: 0 Participated: 0 Study completed: 0	Approached: ? Consented to contact: ? Participated: 0 Study completed: 0
D			Approached: 8 Consented to contact: 7 Participated: 0 Study completed: 0	Approached: ? Consented to contact: ? Participated: 6 Study completed: 6	Approached: ? Consented to contact: ? Participated: 0 Study completed: 0	Approached: ? Consented to contact: ? Participated: 0 Study completed: 0
E	Approached: ? Consented to contact: 7 Participated: 1 Study completed: 1	Approached: ? Consented to contact: 0 Participated: 5 Study completed: 3	Approached: ? Consented to contact: 4 Participated: 2 Study completed: 2	Approached: ? Consented to contact: ? Participated: 1 Study completed: 1	Approached: ? Consented to contact: 5 Participated: 4 Study completed: 1	Approached: ? Consented to contact: ? Participated: 0 Study completed: 0
TOTAL	3	3	5	8	4	0
CUMULATIVE	3/27 (new minimum)	6/27	11/27	19/27	23/27	23/27

Table 4.1

Partial Approach and Consent to Contact Data

Appendix 2.6 Problem Statement Pilot Information

Question Set for Smart Steps AI Pilot

Below are 25 questions. Please rate all questions on two criteria:

1. **Openness** - on a scale from 1-7 how open are the solutions to each question, from 1 = not open at all (i.e. completing a problem using a fixed sequence of steps that must be performed in a given order to solve the problem e.g. brushing your teeth) to 7 = very open (i.e. there are many possible solutions which can be used to solve the problem e.g. planning a wedding)

2. **Difficulty** - on a scale from 1-7 how difficult would it be to solve each of the hypothetical problems, relative to others in this list, from 1 = very easy to 7 = very difficult. Please note: it is likely that you would find many of these problems easy to solve personally, but what we are interested in is how difficult each problem is in comparison to others in this list.

1. How would you manage the situation of your plumber not arriving an hour after they should and you have to leave for a dentist appointment in 10 minutes? *

	1	2	3	4	5	6	7
Openness	◯	◯	◯	◯	◯	◯	◯
Difficulty	◯	◯	◯	◯	◯	◯	◯

2. How would you reduce feelings of loneliness if you felt your family and friends weren't visiting you enough? *

	1	2	3	4	5	6	7
Openness	◯	◯	◯	◯	◯	◯	◯
Difficulty	◯	◯	◯	◯	◯	◯	◯

3. How would you plan a trip to John O'Groats (the northern most tip of Scotland)? *

	1	2	3	4	5	6	7
Openness	◯	◯	◯	◯	◯	◯	◯
Difficulty	◯	◯	◯	◯	◯	◯	◯

4. How would you determine whether to repair or replace a microwave oven that has broken? *

	1	2	3	4	5	6	7
Openness	◯	◯	◯	◯	◯	◯	◯
Difficulty	◯	◯	◯	◯	◯	◯	◯

5. How would you contact someone if your phone battery died and you urgently needed help? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

6. How would you work out whether it is ok to download an app on your phone? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

7. How would you respond if the bus you're waiting for doesn't turn up on time? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

8. How would you organise a surprise party for a friend who you share a flat with? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

9. How would you contact your GP if your phone wasn't working properly and you needed help? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

10. How would you determine if the person calling you on the phone is a spam caller? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

11. How would you organise buying some furniture if you have a very limited budget? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

12. How would you deal with your washing machine stopping working mid-cycle, there is water in it and the door won't open? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

13. How would you determine if you had already taken your medication if you weren't sure? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

14. How would you restart a hobby of yours that you used to enjoy but haven't done for a few years? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

15. How would you manage a situation where you think your phone and keys have been stolen while travelling home on the train? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

16. How would you organise a school reunion for your year group from high school? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

17. How would you get to an unfamiliar part of town if you didn't have your phone on you? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

18. How would you decide on which repairperson to ask to repair your vacuum cleaner if you were alone and unable to ask friends/family for advice? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

19. How would you get the items you need from the supermarket if you realise you have left your shopping list at home? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

20. How would you manage to attend a health appointment if you couldn't remember its time or date? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

21. How would you plan a weekend away with a group of friends? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

22. How would you deal with your heating suddenly going off unexpectedly in your accommodation in winter? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

23. How would you deal with the situation of a neighbour repeatedly playing loud music, after midnight? *

	1	2	3	4	5	6	7
Difficulty	○	○	○	○	○	○	○
Openness	○	○	○	○	○	○	○

24. How would you organise an evening out with an old school friend who you haven't seen for many years who is visiting? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

25. How would you respond if you lost your house keys and were locked out of your flat? *

	1	2	3	4	5	6	7
Openness	○	○	○	○	○	○	○
Difficulty	○	○	○	○	○	○	○

Appendix 2.7 Experiment Script Additional Detail

During the experimental condition, participants were asked:

'[Question]. Please use Smart Steps to let me know [question].'

Participant uses Smart Steps until it has completed its solution

'So, [question]?'

Example:

'How would you plan a weekend away with a group of friends? Please use Smart Steps to let me know how you would plan a weekend away with a group of friends.'

Participant uses Smart Steps until it has completed its solution

'So, how would you plan a weekend away with a group of friends?'

During the control condition, participants were asked:

'[Question]. Please take whatever time you need to let me know [question].'

Example:

'How would you plan a weekend away with a group of friends? Please take whatever time you need to let me know how you would plan a weekend away with a group of friends.'

Appendix 2.8 Experimenter Support Intervention Checklist

Intervention	Code
Repeating instruction	R
Prompting to speak slower	PS
Prompting to speak faster	PF
Prompting to speak louder/quieter (volume)	PV
Prompting to speak more clearly	PC
Technical prompt (e.g. holding phone closer to mouth, pausing before speaking)	PT
Emotional encouragement	E
Restart app	RA
Interpret prompt	IP
Response prompt	RP
Question prompt	QP

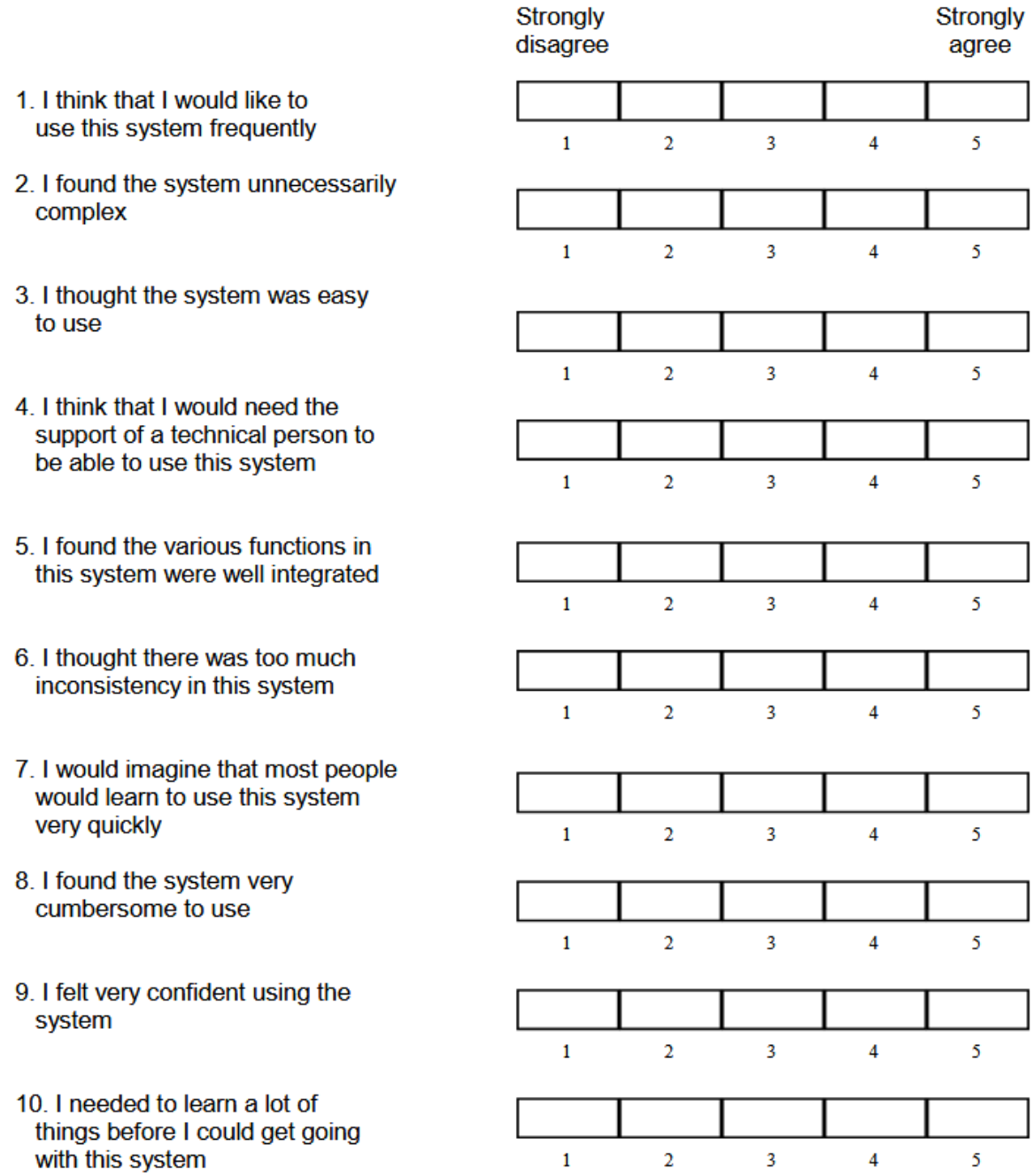
Interpretative Notes

Code	Explanation/notes
R	• Repeating question • Repeating previous instruction • Prompting participant to use SS (when supposed to be, but not, using) • Prompting participant to try again (e.g. when SS has not 'heard' participant)
PF	• Also used for prompting participant to speak without pauses
PV	• Dropped as not required
IP	• Intended as prompt for when the participant incorrectly interpreted problem statement, but dropped as redundant (captured within RP).
RP	• Prompting the participant to say continue/next, usually after error sound (SS not heard). • Prompting participant to change from 'next' to 'continue', or 'I'm finished' to 'finished' or vice versa when SS not understood. • Prompting to answer experimenter instead of using app. • Reminding participant following end of trial to say 'I'm finished' when they have enough information to solve the problem (used if perseverating).
QP	• Prompting participant to ensure they asked roughly the same question as being asked by experimenter. • Reminding participant they do not have ask the *exact* same question (to reduce anxiety, principally) • Reminding participant not to ask additional questions to SS.

N.B. during the experiment, some prompts, particularly prompting participants to say 'continue/next' (RP) were provided non-verbally (e.g. hand gestures) to avoid SS hearing the experimenter. These were not recorded.

Appendix 2.9 System Usability Scale

System Usability Scale



From Brooke (1996)

Appendix 2.10 Reflexivity Statement

I was drawn to this research as I have a broad interest in the intersection of technology and clinical psychology, alongside previous experience supporting individuals with acquired brain injuries. This contributed to a belief that conducting research that has the potential to improve this population's quality of life is a worthwhile task.

I occupied an 'outsider' role with respect to the participant group, and brought my own biases and assumptions about this group, particularly regarding their capabilities. To reflect on and challenge these assumptions, I kept reflective notes, and discussed this in supervision. As a consequence of these discussions, I attended an art group at one of the recruitment sites in a non-clinical, non-researcher capacity. This provided me with an opportunity to engage with individuals with ABI outside of the research context, enhancing my understanding of the heterogeneity of this population and informing how I approached participants in the study. It also gave me a renewed appreciation of the relevance of my project.

Throughout the research process, I remained aware of the power imbalance inherent in working with this population. Efforts were made to minimize potential coercion by clearly communicating the purpose of the study, and ensuring that research processes were as transparent and accessible as possible.

I was also mindful that my own optimism and expectations around the app's efficacy could influence data collection. To mitigate this, interview questions were reviewed in supervision, and I aimed to adopt a neutral, non-leading approach when interacting with participants.

Reflexivity was incorporated throughout the project through the use of supervisory discussions and reflective notes, supporting ongoing consideration of how my assumptions, expectations, and positioning may have shaped the research process and interpretation of findings.

Appendix 2.11 Content Analysis: Initial Reflections from Reading Transcripts

Structure from (Erlingsson & Brysiewicz, 2017) (supplementary data)

Write down your initial impressions. Embrace your intuition. What is the text talking about? What stands out? How did you react while reading the text? What message did the text leave you with? In this analysis phase, you are gaining a sense of the text as a whole.

The transcripts are fairly straightforward and brief, there's not much hidden meaning. Participants are upfront about what they think about the app, and generally are saying similar things. Impressions are mainly positive, and some said the app helped them to think in novel ways.

I'd said 'you can be honest' to elicit more accurate feedback from participants during the dislikes question. This helped to facilitate more honest answers I think on a few occasions (e.g. 14), though participants were generally honest anyway, which perhaps is partly a consequence of their frontal lobe brain injuries.

I found it amusing reading the transcripts back, some of the answers are comical. Maybe sometimes some participants weren't taking it all that seriously. But they tended to follow up with actual answers.

A few mentioned that they'd need more time with the app to make a judgement about e.g. if it had any impact on their problem-solving abilities.

A few found it frustrating when SS couldn't pick up what they were saying, or when the app didn't stop describing its solution when prompted by the user.

There's mixed views on the voice, some saying it's condescending. Multiple comments about the app not understanding participants' speech, either due to mild speech issues or accent – 'aye they'll no understond oor tone and oor slang' – 19.

I'm now wondering if I should have added a question about the overall emotional experience of using the app. The SUS questionnaire captures usability (and learnability to some extent), and there's some overlap between the questionnaire and interview, but knowing how it made participants feel would have been useful. Sometimes this was obvious, such as frustration, but would have been interesting to understand this in more depth, and would have brought deeper understanding to comments around things like companionship, which might be relevant in this population.

Also wondering if I should have included a question that asks 'would you recommend this app?' with a binary yes/no response. One participant said this explicitly.

Think this will be a more straightforward coding and analysis. I wonder if Thematic Analysis is still the most appropriate approach.

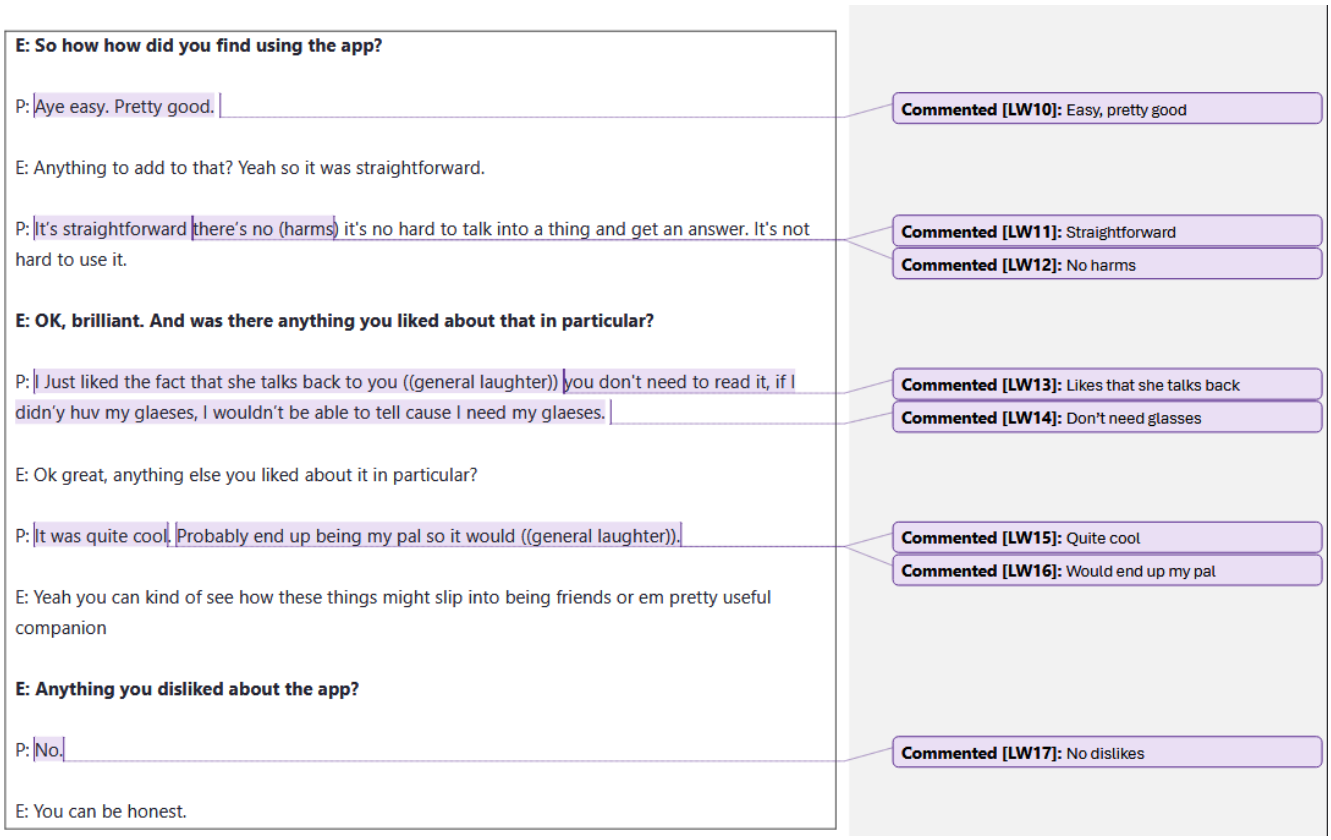
Appendix 2.12 Content Analysis Initial Coding Process

From: (Erlingsson & Brysiewicz, 2017)

Meaning Units, Initial Coding and Categories

Analytic Aim

This analysis is attempting to understand participants' views about the app and to capture their opinions with respect to its utility. This is important as we know that many ATC are not routinely used, even if found to be effective. It's not just about whether it was effective, but whether it is usable, and acceptable to participants.



P: No it was it was easy, straightforward. There's nae complication with it at all. It speaks loud and clear. There's nae higgldypiggldy with it or anything like that. It's it's it's mare or less straightforward.

E: It's straightforward yeah, ok that's good to hear. Anything you found difficult?

P: Naw. You don't need to be Einstein to work out how that app. It's quite straightforward and it's quite easy to use.

E: That's really good to hear, good good.

E: Do you think the app had any effects on how you solve problems?

P: I didn't have enough time to ask to ask it that many questions, but aye I think it would have. I thought there was mare questions I would've asked. I think it will have an effect on how I change like change different ways of dain things.

E: Do you have any sense of you know if you had longer with the app how it would change how you'd solve problems, what would be your guess?

P: Mibbe, probably, aye. If you weren'y savvy it would help you. But I'm pretty savvy, so.

E: No I think you coped with it really really well so that's brilliant.

E: And then last question and then we will let you go is do you have any suggestions for us for improving the app?

P: I think it goes it all right no? There's nothing I could not add to that. That's it's pretty clever. You've done well wae it, hope it makes you plenty of [money].

Commented [LW18]: Easy, straightforward

Commented [LW19]: Loud and clear

Commented [LW20]: Straightforward

Commented [LW21]: Not enough time with app

Commented [LW22]: Might have impacted problem-solving

Commented [LW23]: Provides different ways of doing things.

Commented [LW24]: Might've helped PS

Commented [LW25]: Would have been helpful if not savvy

Commented [LW26]: It's good

Commented [LW27]: No additional suggestions

Commented [LW28]: It's clever

Commented [LW29]: Hope it makes you money

Meaning units	Codes
Easy, pretty good	Ease of use, useful tool
Straightforward	Ease of use
No harms	No harms
Likes that she talks back	Companionship
Don't need glasses	Accessibility
Quite cool	Cool
Would end up my pal	Companionship
No dislikes	No dislikes
Easy, straightforward	Ease of use
Loud and clear	Accessibility
Straightforward	Ease of use
Not enough time with app	Not enough time
Might have impacted PS	Impact on PS
Provides different ways of doing things	Novel approach
Might've helped PS	Impact on PS
Would've been helpful if you're not savvy	Supports PS
It's good	Useful tool
No additional suggestions	No suggestions
It's clever	Useful tool
Hope it makes you money	Perceived value

Meaning units	Codes	Categories
Easy	Ease of use	Ease of use
Straightforward	Ease of use	
Easy, straightforward	Ease of use	
Straightforward	Ease of use	
Don't need glasses	Accessibility	Accessibility
Loud and clear	Accessibility	
Would end up my pal	Companionship	Companionship
Likes that she talks back	Companionship	
Pretty good	Useful tool	Useful tool, positive experience using app
It's good	Useful tool	
It's clever	Useful tool	
Quite cool	Cool	
Hope it makes you money	Perceived value	
Might have impacted PS	Impact on PS	Impact on PS
Might've helped PS	Impact on PS	
Would've been helpful if you're not savvy	Supports PS	
Provides different ways of doing things	Novel approach	

Meaning unit	Coding Flag	
No additional suggestions	No suggestions	Absence of negative feedback
No harms	No harms	
No dislikes	No dislikes	
Not enough time with app	Not enough time	Not enough time

Appendix 2.13 Category Analysis: Codebook

Category: Technical Performance & Faults

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Comparison	COMP	Positive comparison of SS to other software e.g. Siri, Google.	Explicit statements comparing SS as on par or favourably to other similar software e.g. "better than".	N/A	"That might have been a better solution than just Googling things" - P2 "It's pretty much like Google it's not dissimilar" – P11
Cut	CUT	Participant refers to the app having cut their speech off.	Explicit statements describing the app cut off the participant, or would not let them finish.	N/A	"Yeah like it never gave me an extra second to think what I was going to say" – P22
Fast	FAST	Participant describes the app as fast.	Explicit statements describing the app as being quick, fast etc.	Feature request for the app to be quicker (SPEED).	"It's quick as well which is nice ehm there isn't too much waiting or wondering if you've you've correctly sort of framed the problem to solve which is useful because you're not

					waiting, wondering." – P10 "It gave you the answers right away" - P13
Flexible	FLEX	Participant implies the app is flexible, or adaptable, resilient, responsive.	Explicit statements describing the app as being flexible, able to interpret what the participant meant, or able to answer multiple questions (or similar).	App understood what participant meant (AUND), more general positive appraisals of using app (PX).	"...It's easy you're going down the wrong rabbit hole well just ask another question." – P9 "It always gives you an answer" – P13
Slow	SLOW	Participant describes the app as too slow, cumbersome.	Explicit statements that describe the app as slow, cumbersome.	Feature request for the speed of app to be faster (SPEED).	"Cumbersome, isn't very quick" – P4
Stop	STOP	Statements that indicate the app did not finish outlining its solution when prompted by the participant to stop.	Explicit statements indicating the app did not stop when instructed to.	N/A	"Yeah it kept going as well but it's just needs restarting" – P12 "Only thing is sometimes when you're finished wae it it keeps talking to you." - P13

Understand	UND	Participant states that the app could not understand their speech.	Explicit statements that describe the app being unable to understand the participant.	Feature requests to improve speech recognition (RECOG).	“Couldn’t understand me” – P7 “Yeah naw, I disliked it when it was eh it couldn't understand what I was saying” – P12 “Aye they’ll no understond oor tone and oor slang.” – P19
Unfinished	UNF	Participant describes/implies the app feels unfinished.	Explicit statements describing the app as unfinished, still in development, requiring polishing.	General negative appraisals of the experience of using the app (NX).	“I'm aware that there are glitches with new technology” – P3 “I'm pretty sure that you're not finished with it… you know I think you’re a good bit away” – P11

Category: Usability

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Accessibility	ACC	Statements suggesting the app was accessible, and helped them overcome physical, sensory, or other barriers.	Explicit statements describing the app as being accessible, or specific features indicating accessibility e.g. the audio/voice being loud and clear.	General positive experiences (PX), and statements about ease of use (EOU).	"If I didn'y huv my glaeses, I wouldn't be able to tell"; "it speaks loud and clear" – P1
App understood	AUND	Statements indicating the app understood what participant meant.	Explicit statements describing that the app understood what the participant was meaning.	Participant implies the app is flexible, or adaptable, resilient, responsive. (FLEX)	"It interprets quite well what you're meaning" – P14 "Yeah it seemed quite responsive it seemed to understand what I was saying when I asked it each time"- P22
Learning curve	CURVE	Statements indicating the participant felt they would need some time to get used to the app.	Explicit statements describing the participant would need more time to get used to the app without support from others.	Statements indicating the participant would need more time with the app to provide a value judgement (NET). Statements indicating the participant would require further support (SUP).	"It's just getting used to you know" – P11 "I think it'd be something I think you'd get used to… I just wasn't used to it" - P20

Difficult to use	DIF	Statements suggesting the app was difficult, hard to use.	Explicit statements indicating the app was difficult or challenging to use.	Broader statements about negative experience of using the app (NX).	"It was a bit difficult" – P8
Ease of use	EOU	Statements describing the app as easy to use, simple, straightforward, uncomplicated.	Explicit comments that the app is easy to use, simple, straightforward, or references to lack of complexity, statements about not needing high level of skill to use.	Statements about accessibility (ACC). Statements about positive experience/enjoyment of using app (PX).	"It's straightforward…it's not hard to use it" – P1 "Thought it was quite simple" – P13
Learnability	LEARN	Statements describing that it was quick or easy to pick up/learn how to use the app.	Explicit statements indicating the app was quick or easy to learn.	Statements indicating more general ease of use (EOU).	"Like I think it could have worked out without some instructions" – P6
Support needed	SUP	Statements acknowledging the participant or other users would need additional support to use the app, or would need to have prior knowledge.	Explicit statements indicating further support would be needed for the user.	Statements describing any difficulties in use being due to firs time use of the app (TEETH).	"I need more help to navigate the app." - P4 "It wasn't for stupid people" - P5
Tailored to brain injury population	TAI	Statements indicating the participant thinks the app is tailored to the needs of the brain injury population.	Explicit statements indicating the app is tailored to the brain injury population.	General statements about the app's accessibility (ACC).	"It can do a good job of um ((pause)) recognising difficulties that a person with brain

					injury um needs" – P14
Teething problems	TEETH	Difficulties experienced are to be expected as first time using app.	Explicit statements indicating difficulties experienced are due to first time using the app.	Statements that further support is required for the participant to use the app (SUP).	"It's the fact you're using something for the first time and again getting used to doing things" – P2

Category: Personalisation & Feature Requests

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Alarm	ALARM	Participant suggests an alarm function could be integrated into the app.	Explicit statement describing participant requesting an alarm function is embedded in app.	N/A	"Well you could actually put an alarm on it for my medication" – P11
Dynamic	DYN	Participant suggests the app could respond dynamically based on what it is used for/what questions are being asked.	Explicit suggestions to integrate additional features based on app use.	Statements suggesting the app could be linked with other services (LINK).	"Ohh, I don't think so no I think it's I think it's adequate unless it wants to add things that are relevant to what we're using the app for do you know what I mean?" - P15

More solutions	FEW	Participant suggests the app should provide more than just one potential solution.	Explicit suggestions to provide more than one solution.	Statements indicating the app gave too basic or few solutions (BAS), but no suggestion is made to increase number of solutions.	“Think it did tend to give you one way to do something whereas I think people generally would need a couple of ways to try and sort something out” - P20
Happy	HAP	Participant suggests the app should make the user happy.	Explicit suggestions that the app should make the user happy.	N/A	“…Keep the person happy” - P8
Link to other services	LINK	Participant suggests linking the app with other services e.g. google maps, services e.g. to repair lock.	Explicit suggestions of linking the app with other services.	Statements suggesting the app could integrate features based on what the app is being used for/what questions are being asked (DYN).	“Linking it to I suppose Google Maps reviews that kind of thing where that that would give people some kind of insight into it would be quite might be quite useful.” - P10
Call by name	NAME	Participant suggests the app should call the user by their name.	Explicit suggestions the app should call the user by their name.	N/A	“I would get them calling them their patient's name by name” - P5

Speech recognition improvement	RECOG	Participant suggests the app could be better at recognising the user's speech/accent.	Explicit suggestions of improved speech recognition.	Statements describing the app as being unable to understand the speech of the participant (UND), without suggesting this should be improved.	"Add Scottish language and that" - P17
Faster	SPEED	Participant suggests the app should be quicker.	Explicit statements that suggest the app should be quicker.	Participant describes the app as too slow, cumbersome without suggesting improvement.	"It has to be a bit quicker." – P4
Text on screen	TEXT	Participant suggests the app could display the text of questions/answers on screen.	Explicit statement describing participant requesting text in addition to speech is added to app.	N/A	"It could maybe when the app responds to you like put the text of what the app has said on this screen as well" – P6

Category: Quality of Solutions

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Good answers	APG	Participant indicates the app provided good or clever answers.	Explicit statements describing answers as good, clever or similar.	Statements indicating the perceived utility or value of the app for the participant or others (USE).	"I think she came back with some good answers" - P5

Basic answers	BAS	Participant indicates the app provided basic, non-specific, vague, limited solutions, framed negatively.	Explicit statements describing solutions as basic, vague, limited.	Statements describing solutions as basic in a positive way (SIMP).	"If anything, it like it gives like the most basic form of like steps like it's not very specific" – P6 "The responses are quite vague" – P10 "Think it did tend to give you one way to do something whereas I think people generally would need a couple of ways to try and sort something out" - P20
Clear answers	CLEAR	Participant indicates the responses were clear.	Explicit statements describing responses as being clear.	Statements describing solutions as being basic but in a positive way (SIMP).	"It was quite clear and concise with whit it wanted ye' to dae" – P15
Detailed answers	DETAIL	Participant indicates the responses were detailed, framed positively.	Explicit statements describing responses as being lengthy or detailed in a positive sense.	Descriptions of the answers being lengthy, or too long in a negative way (LONG).	"Aye it was (geein) ye gawn through a list eh hings instead eh how do you put it it was going to it in mare

					detail than whit I wid know" – P19
Long answers	LONG	Participant indicates the responses were too lengthy, framed negatively.	Explicit descriptions of the answers being lengthy, or too long.	Statements about responses being lengthy, but framed positively (DETAIL).	"Some of the things maybe could have finished a bit earlier" – P2
Unimportant responses	NIQ	Participant indicates the app asked questions, or provided responses that were unimportant.	Explicit statements describing the app as providing unimportant responses or questions.	Statements indicating the app asked too many questions (TMQ).	"It asks… not important questions." - P4
Step-by-step	STEP	Participant indicates specifically that they liked that solutions were broken down into steps.	Explicit statements indicating the participant liked that the app broke down the solution into steps	Statements indicating more generic descriptions of the app being accessible (ACC), or tailored to the brain injury population (TAI).	"Um the fact that it broke down the steps or the rational steps in making decisions or process of decision making" – P3
Simple	SIMP	Participant indicates the responses were simple, short, and concise in a positive way.	Explicit statements describing the responses as simple, straightforward	Statements describing the use of the app as simple, straightforward (EOU). Statements describing responses as being clear (CLEAR).	"But the answers weren't daft, but they were relatively simple answers" – P2 "It was quite clear and concise with

					whit it wanted ye' to dae" – P15
Too many questions	TMQ	Participant indicates the app asked too many questions.	Explicit statements describing the app as asking too many questions.	Statements indicating the app asked unimportant questions (TMQ).	"It asks too many questions." - P4

Category: Usefulness

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
App has potential	POTA	Participant describes the app as having potential in the future.	Explicit statements about the app having potential in the future.	More generic positive appraisals of the app (PX), or negative appraisals (NX), or indications the app is unfinished (UNF).	"I think it will ehm flourish ehm ((pause)) I think there's there's potential in it there" - P11
Similar solutions to user	PSSIM	Participant indicates the app's solutions were similar to what they would have responded themselves.	Explicit statements highlighting similarity of app's solution to participant's own reasoning.	Statements about the app providing good responses (APG).	"Most of the questions I could relate to... and what I already had in my head anyway it was coming up" – P22

Utility	USE	Statements indicating the perceived utility or value of the app for the participant or others.	Explicit statements expressing the usefulness of the app (or similar).	More generic positive appraisals of the app (PX). Statements indicating the app is easy to use (EOU).	"I can see why for some people that would be very very useful" – P10 "It'd be good for everybody you know" – P11
Lack of utility	XUSE	Participant indicates the app is not needed, or would not be useful to them personally.	Explicit statements describing that the participant does not need the app at present, or would not benefit from it at present.	More generic negative appraisals of the app (NX).	"I don't think it's something that's particularly useful for me at the moment just kind of at the stage that I'm at" – P6

Category: Impact on Problem-solving

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Impact on problem-solving	PS	Participant indicates they believe the app did have an impact on, or supported their problem-solving.	Clear and explicit positive affirmations e.g. "yes" in response to question.	Participant did not have enough time using the app to answer question meaningfully (NET).	"Yes I think it gives you the right step to take and I think that's vitally important because sometimes you don't know where to go" -P5

					"...because also verbalising like your plan helps you think through it I think" - P6
Promoted reflection and novel ways of thinking	NOV	App provided new ways of thinking, information, or novel solutions to problems, or promoted reflection.	Explicit statements describing the app as prompting reflection, or novel approaches to solving problems.	Statements indicating the app impacted PS but did not promote further reflection or indicate novel ways of thinking (PS).	"...Answers have come back and I've thought I wouldn't have thought of that" – P2 "...It opens your mind" – P5
No impact on problem-solving	XIMP	Participant indicates they believe the app did not have an impact on, or supported their problem-solving in response to 'impact on PS' question.	Explicit "no" or similar in response to question.	Participant did not have enough time using the app to answer question meaningfully (NET).	"Em I don't think so? No I don't think it kind of had any effect" – P6

Category: Suitability & Risk

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Inappropriateness for some patients	APR	Statements indicating the app might not be suitable for some patients e.g. with AWI	Explicit statements describing the app may not be suitable for some patients.	Statements describing the app as increasing risk (IR).	"…I can see it being an issue particularly if something happened to the person if they did something themselves…". – P2
Increases risk	IR	Statements indicating the app might increase risk or negative consequences for some individuals.	Explicit statements that the app might result in negative consequences, such as access to information that would be harmful, or promoting behaviour that would be harmful.	Judgements about the appropriateness of the app for users (APR).	"I might have accessed things if I had the option to do that that maybe I shouldn't have been and I'm talking about health matters" – P2
No harms	NH	Statements indicating the participant believes there are no harms of using app.	Explicit statements indicating the participant believed there were no harms involved in using the app.	Statements about the app actively reducing harms/risks (RR).	"There's no harms" – P1
Reduces risk	RR	Statements describing the app as being able to reduce or protect the user from risk.	Statements implying the design of the app, being tailored to the brain injury population, may reduce risk.	Statements indicating the participant believes there are no harms of using the app (NH).	"I'd like to think that maybe [the app] wouldn't come up with the

					nitty gritty bad stuff right away" – P2

Category: Affective & Relational Experience

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Adjustment	ADJ	App may have helped with the adjustment to having a brain injury.	Explicit statements describing the app as facilitating emotional adjustment to having a brain injury.	Statements describing the general utility of the app (USE).	"It maybe would have advanced the whole process, which would have made me sink into the thing a bit better than I did when I was sort of struggling a little bit."; "it might have got me quicker to settling into the overall rehabilitation" – P2.
Clever	CLEV	Participant indicates the app was clever.	Explicit statements describing the app as clever, smart etc.	Statements indicating solutions provided by the app were good (APG).	"It's pretty clever" – P1 "I think it's genius" – P21

Companionship	COM	Statements suggesting that app feels like, or could be considered a companion, a friend.	Explicit statements comparing the app to a friend, or personalising interaction in a positive way. Or statements indicating the app might have reduced loneliness/isolation.	General positive statements about the app (PX). Positive relational features (e.g. VOICE).	"Probably end up being my pal so it would" – P1 "It's nice that you've got somebody to go to." – P5 And then I like that it's kind of a conversation between you and the app" – P6
Interaction	INT	Participant makes comment about interaction between themselves and the app.	Explicit statements describing the interaction between user and app.	Statements regarding companionship (COM).	"Making sure I actually asked the the question that would give me the correct, you know, correct eh answer. You know, garbage in garbage out and so as a way of it I had to be very precise about the question I asked because they're all very useful and they do have access to all sorts of incredible

					information but they don't think. So the better the question, the better the outcome for sure." – P9
No judgement	NOJ	Statements that indicate the app did not judge them.	Explicit statements describing the app did not judge them, they did not feel judged.	Statements suggesting that app feels like, or could be considered a companion, a friend (COM).	"There's no judgement". – P5
Negative experience	NX	General statements indicating a negative experience with the app.	Explicit statements of negative experience e.g. frustration, when using the app.	More specific negative value judgements about the app (e.g. UND).	"Didn't pick up what I was saying. Really annoying". - P8
Positive experience/affect	PX	General expressions of enjoyment, liking, or having a positive emotional experience when using the app.	General statements implying a positive experience when using the app.	More specific positive value judgements about the app (e.g. CLEV, COMP).	"It was quite cool" – P1 "She's good" – P5
Liked voice	VOICE	Participant positively comments on the voice used in the app.	Explicit statements about participants liking the voice, or features of the voice (e.g. accent).	Statements suggesting that app feels like, or could be considered a companion, a friend (COM). General positive appraisals of the experience of using the app (PX).	"The voice was not condescending" – P14
Disliked voice	XVOICE	Participant negatively comments on the voice used in the app.	Explicit statements about participants not liking the voice or features of the voice (e.g. accent).	General negative appraisals of the experience of using the app (NX).	"She's ever so slightly bland and condescending" – P9

					"Just uh the accent" - P14

Category: Engagement Intentions

Code Name	Abbreviation	Definition	Inclusion Criteria	Exclusion Criteria	Example Quote
Intention to use	ITU	Participant expresses a statement of wanting to or intending to use the app.	Explicit statements of intention to use the app, or desire to use the app, in the future.	Statements indicating intentions to recommend the app (REC).	"I would have used it" – P2. "Uh I would like to use it to solve problems" - P14
Intention to Recommend	REC	Participant describes that they intend on recommending the app to others.	Explicit statements describing participants' intention to recommend the app.	Statements indicating intention to use the app (ITU).	"Yeah I'll definitely recommend it and sell it to friends." – P21
Want for further interaction	WAQ	Participant describes that they wanted to interact with the app further.	Asking additional questions	Statements indicating intention to use the app (ITU).	"I wanted to ask it other questions that were unrelated to the questions" – P2

Table 4.2 Content Analysis Codebook

Coding Flag: Absence of Feedback

Code Name	Abbreviation	Definition
No dislikes reported	NDR	Statements indicating that there were no dislikes in response to 'dislikes' question.
Not enough time	NET	Statements indicating the participant did not have enough time with the app to make a judgement about e.g. likes/dislikes, or whether the app impacted their PS.
No difficulties reported	NFR	Statements indicating that there were no difficulties when using the app, in response to 'difficulties' question.
No suggestions for improvement	NOSUG	Statements indicating that there were no suggestions for improvement of the app in response to 'suggestions' question.

Table 4.3

Content Analysis Coding Flags

Appendix 2.14 Solution Rating Examples

Instructions Below, and on the subsequent tabs you will find problems given to participants to solve, and their associated solutions.

Your job is to rate each solution based on its:
1. number of relevant steps
2. effectiveness

A relevant step is a concrete action that moves one towards solving or preventing the problem.
A problem-solving strategy is considered effective if it maximizes positive and minimizes negative short and long-term consequences, both personally and socially (D'Zurilla & Goldfried, 1971)

When rating solutions for effectiveness, please use the seven-point scale below, and use the full range of the scale where a rating of 1 means that the solution was not at all effective, and a 7 means the solution was extremely effective. The mid-point of the scale, 4, means that the solution was moderately effective.

Effectiveness scale

Not at all effective			Moderately effective			Extremely effective
1	2	3	4	5	6	7

Example For example,
What would you do if you forgot about an important appointment that was scheduled for the morning? The office has already emailed asking you why you didn't attend and have said you may be charged a fee.

A response that might be considered **not at all effective (1)** is:
Dunno, I'd probably ignore the email.
This solution has 1 relevant step - ignoring the email.

A response that might be considered **extremely effective (7) is:**
I'd reply to the email straight away and apologise for missing the appointment. I'd explain that I forgot and ask if it's possible to reschedule. Then I'd check their policy about cancellation fees and see if there's anything I can do to reduce the charge. If I needed to, I'd pay the charge. After that I'd put reminders in my calendar, so it doesn't happen again.
This solution has 8 relevant steps - replying to the email, apologising, explaining the reason, asking to reschedule, checking cancellation policy, attempting to reduce fee, paying if necessary, and setting calendar reminders.

A response that might be considered **moderately effective (4) is:**
I'd reply to the email and apologise for missing the appointment. I'd ask if I could book another time. I'd pay the fee and try to remember next time.
This solution has 5 relevant steps - replying to the email, apologising, asking to reschedule, paying fee, trying to remember.

Scored Examples

Question 6 How would you organise a school reunion for your year group from high school?

Response 1

I'd message all my pals that was on my phone and ask them if they wanted to go for a party and then wait and see what they said back. And if there wasn't enough, I wouldn't do it. I'd organise it and DJ myself. I don't drink but they'd probably do it in a bar or something, so, I'd organise a bar where it had a backroom where I could play my music and let them get sozzled if that's what they want.

Number of relevant steps	4
Effectiveness	4

Response 3

I would create a list of people to attend the party. I would contact them and find out if they had suitable dates.
I would then decide on date for the party, and I would decide on the theme. Any events, food and drink for the party, I would send invitations to the group of friends and seek their responses, creating a final list of attendees to the party. Closer to the event, I would have a chase up on a reminder seeking any payments or information or whatever for the event and look forward to the event.

Number of relevant steps	8
Effectiveness	6

Response 11 My school's reunion is the 13th January. Sorry. December. WhatsApp. And chat with the group. Get a venue.

Number of relevant steps	2
Effectiveness	2

Question 2 How would you respond if the bus you're waiting for doesn't turn up on time?

Response 3 I would look at other travel options and speak to the fellow commuters.

Number of relevant steps	2
Effectiveness	4

Response 10 I would check the timetable either the paper copy that was on the side of the bus shelter, or if there was a digital display indicating whether it had been cancelled or delayed or amended or whatever. I would probably check using my phone to see if there were any other bus routes nearby that I could take from the stop I was at. Failing that I would probably use a taxi if it was particularly pressing for me to achieve a place by a particular time.

Number of relevant steps	3
Effectiveness	6

Response 13 I would phone the bus company. And ask what happened to it. And I would also check online first.

Number of relevant steps	3
Effectiveness	3

Question 10 How would you respond if you lost your keys and were locked out of your house/flat?

Response 4 I would ask a key smith to come to the house to locate my keys and gain access.

Number of relevant steps	1
Effectiveness	3

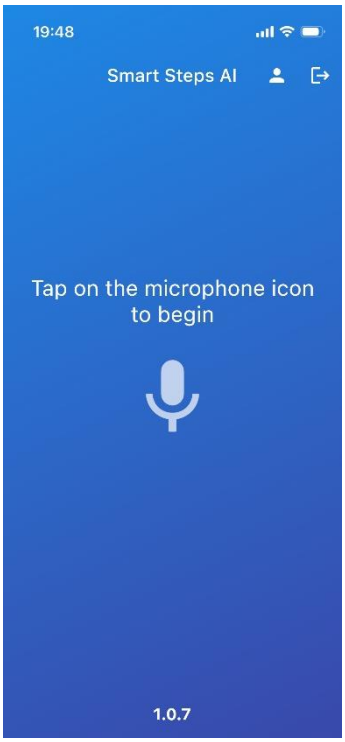
Response 10 OK, so get in touch with a trusted friend or neighbour who may have a spare key. Failing that, get in touch with a local locksmith who can who can actually gain entry to the property.

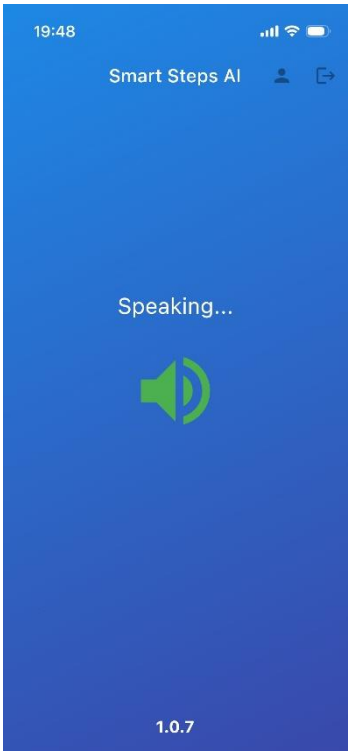
Number of relevant steps	2
Effectiveness	5

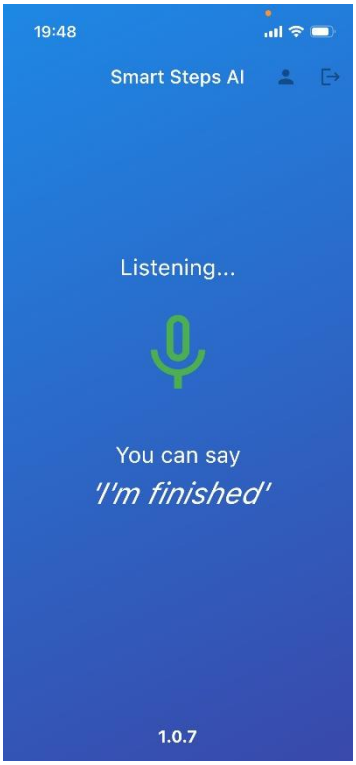
Response 21 Well, you wouldn't want to listen to it. I'd be cursing calling myself all the stupid buggers on the sun.

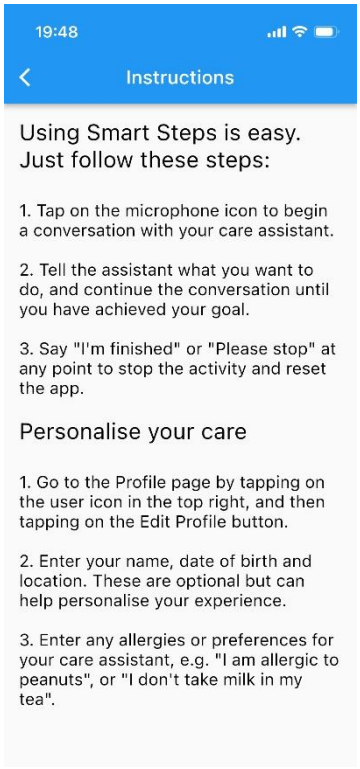
Number of relevant steps	0
Effectiveness	1

Appendix 2.15 Smart Steps AI Screenshots









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