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Chung CSY, Pollock A, Campbell T, Durward BR, Hagen S

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Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

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ABSTRACT

Background

Executive functions are the controlling mechanisms of the brain and include the processes of planning, initiation, organisation, inhibition, problem solving, self monitoring and error correction. They are essential for goal-oriented behaviour and responding to new and novel situations. A high number of people with acquired brain injury, including around 75% of stroke survivors, will experience executive dysfunction. Executive dysfunction reduces capacity to regain independence in activities of daily living (ADL), particularly when alternative movement strategies are necessary to compensate for limb weakness. Improving executive function may lead to increased independence with ADL. There are various cognitive rehabilitation strategies for training executive function used within clinical practice and it is necessary to determine the effectiveness of these interventions.

Objectives

To determine the effects of cognitive rehabilitation on executive dysfunction for adults with stroke or other non-progressive acquired brain injuries.

Search methods

We searched the Cochrane Stroke Group Trials Register (August 2012), the Cochrane Central Register of Controlled Trials (*The Cochrane Library*, August 2012), MEDLINE (1950 to August 2012), EMBASE (1980 to August 2012), CINAHL (1982 to August 2012), PsycINFO (1806 to August 2012), AMED (1985 to August 2012) and 11 additional databases. We also searched reference lists and trials registers, handsearched journals and conference proceedings, and contacted experts.

Selection criteria

We included randomised trials in adults after non-progressive acquired brain injury, where the intervention was specifically targeted at improving cognition including separable executive function data (restorative interventions), where the intervention was aimed at training participants in methods to compensate for lost executive function (compensative interventions) or where the intervention

involved the training in the use of an adaptive technique for improving independence with ADL (adaptive interventions). The primary outcome was global executive function and the secondary outcomes were specific components of executive function, working memory, ADL, extended ADL, quality of life and participation in vocational activities. We included studies in which the comparison intervention was no treatment, a placebo intervention (i.e. a rehabilitation intervention that should not impact on executive function), standard care or another cognitive rehabilitation intervention.

Data collection and analysis

Two review authors independently screened abstracts, extracted data and appraised trials. We undertook an assessment of methodological quality for allocation concealment, blinding of outcome assessors, method of dealing with missing data and other potential sources of bias.

Main results

Nineteen studies (907 participants) met the inclusion criteria for this review. We included 13 studies (770 participants) in meta-analyses (417 traumatic brain injury, 304 stroke, 49 other acquired brain injury) reducing to 660 participants once non-included intervention groups were removed from three and four group studies. We were unable to obtain data from the remaining six studies. Three studies (134 participants) compared cognitive rehabilitation with sensorimotor therapy. None reported our primary outcome; data from one study was available relating to secondary outcomes including concept formation and ADL. Six studies (333 participants) compared cognitive rehabilitation with no treatment or placebo. None reported our primary outcome; data from four studies demonstrated no statistically significant effect of cognitive rehabilitation on secondary outcomes. Ten studies (448 participants) compared two different cognitive rehabilitation approaches. Two studies (82 participants) reported the primary outcome; no statistically significant effect was found. Data from eight studies demonstrated no statistically significant effect on the secondary outcomes. We explored the effect of restorative interventions (10 studies, 468 participants) and compensative interventions (four studies, 128 participants) and found no statistically significant effect compared with other interventions.

Authors' conclusions

We identified insufficient high-quality evidence to reach any generalised conclusions about the effect of cognitive rehabilitation on executive function, or other secondary outcome measures. Further high-quality research comparing cognitive rehabilitation with no intervention, placebo or sensorimotor interventions is recommended.

PLAIN LANGUAGE SUMMARY

Cognitive rehabilitation for executive function problems after brain injury

Executive function is the term used to describe the brain processes that we use to organise ourselves and solve problems. Executive function is frequently affected when the brain is damaged through trauma or from an internal cause such as a stroke. It has been estimated that around 75% of people will have executive function difficulties after a stroke. People with executive function difficulties (executive dysfunction) often find it difficult to learn new ways of doing daily activities, such as dressing themselves. This can make it very difficult for them to learn ways to deal with other problems, such as movement difficulties, which also occur as a result of their brain injury. Cognitive rehabilitation is a type of therapy that aims to improve people's attention, memory or executive function. If it is possible to improve executive function, then more people with brain injury might become more independent with activities of daily living, and might respond better to their rehabilitation. We investigated how effective cognitive rehabilitation interventions are at improving executive function after brain injury. We found 19 relevant studies involving 907 people. We were able to combine the results of 13 of these studies including 660 participants (395 traumatic brain injury, 234 stroke, 31 other acquired brain injury). Only two of the studies (82 people) reported the outcome in which we were most interested (a general measure of executive function). We found no evidence that cognitive rehabilitation interventions were helpful for people with executive dysfunction for any other outcomes. We recommend that more research is carried out to determine whether cognitive rehabilitation can improve executive function after stroke and brain injury.

BACKGROUND

Executive functions are the controlling mechanisms of the brain and include the processes of planning, initiation, organisation, inhibition, problem solving, self monitoring and error correction (Evans 2003). They are essential for goal-oriented behaviour and responding to new and novel situations. These processes are executed through the mechanism of working memory where the cognitive processes of attention and memory are controlled by a central executive system (Baddeley 1974). As 75% of stroke survivors experience working memory impairment (Riepe 2003), they will also experience executive dysfunction as a consequence.

Several systematic reviews have concluded that the effectiveness of cognitive rehabilitation interventions cannot be supported or refuted (Bowen 2007; Cicerone 2005; Lincoln 2000). Despite authors finding some evidence that cognitive rehabilitation improved attention and unilateral neglect on paper-and-pen tests, there was no evidence of improved functional ability. These reviews, with the exception of one (Cicerone 2005), focused on attention and memory, but not executive function. Thus, the relationship between functional ability and executive function requires investigating.

Description of the condition

The impact of executive dysfunction was demonstrated in a cohort study by Walker 2004 who investigated the progress of 30 participants with stroke in regaining the ability to put on a polo shirt independently. Participants with cognitive impairment, but no motor impairment, were successful in putting on the polo shirt. Those with motor impairment, but intact cognition, also regained independence in the dressing task. However, the participants with both motor and cognitive impairment did not regain independence in this dressing task.

A possible explanation for these findings is related to the ability to plan, problem solve and self monitor, that is, executive function. There was no requirement for problem solving in the group with intact motor ability as they were not required to change their dressing method; despite having impaired cognition, only basic levels of attention and memory were required for this routine task. The participants with impaired motor ability were able to use their intact executive function to problem solve and develop alternative methods for putting on the polo shirt. However, the participants with both motor and cognitive impairment could not use a routine method for putting on the polo shirt, and did not have the necessary executive function to support this process.

The development of basic cognition may not be adequate to develop the ability to perform complex, novel and adaptive tasks without addressing executive function. Thus, interventions to reduce executive dysfunction may be the key to improved function.

Description of the intervention

Cognitive rehabilitation is a “systematic, functionally oriented service of therapeutic activities that is based on assessment and understanding of the patient’s brain-behavioural deficits” (Cicerone 2005). Executive function training is a component of cognitive rehabilitation that also includes attention and memory training. There are a variety of cognitive rehabilitation interventions that may be used in the rehabilitation of people with executive function problems. They can be divided into one or more of three broad categories.

1. Cognitive rehabilitation interventions, which are specifically targeted at improving components of executive function. Methods are characterised by people working to improve the actual skill through improved awareness, performance opportunity and repetition. These interventions include:

- i) planning and organisation skills development (e.g. training that begins with tasks with fewer stages building up to more complex tasks);
- ii) problem-solving and strategy formation techniques including goal management training (e.g. training in conscious problem-solving techniques that are intended to become more automatic with practice);
- iii) self awareness and self regulation of behaviour (e.g. pre- and post-task scoring to develop awareness of task performance);
- iv) initiation of behaviours (e.g. goal-related scheduled tasks to train initiation);
- v) inhibition of prepotent responses (e.g. training tasks designed to elicit conscious responses dependent on inhibiting an automatic response such as sentence completion with words that do not make sense).

2. Cognitive rehabilitation interventions that compensate for executive function impairment. Methods are characterised by the use of internal or external cognitive devices to compensate for fragmented or disorganised executive function processes, or to increase peoples’ awareness of their own performance to inform strategy formation. These are aimed towards people performing functional activities and activities of daily living (ADL) using their methods employed prior to brain injury or the self development of new methods. Interventions include:

- i) use of written strategies and electronic technology (e.g. using a mobile phone timer to stop one activity and move to another);
- ii) self instruction techniques (e.g. self talk through the stages of a task to be undertaken);
- iii) feedback methods including mirror and video feedback (e.g. training in the use of self reflection from the person viewing a video recording of their own task performance);
- iv) systematic problem-solving procedures (e.g. training in the use of self cueing stages including, stop, think through the stages of the task to be undertaken, perform the stages one at a time, review performance).

3. Cognitive rehabilitation interventions that train people to use adaptive methods for increasing independence in ADL skills. Methods are characterised by the use of internal or external cognitive devices to compensate for attention, memory or sequencing impairment when applied to specific ADL training in alternative techniques for undertaking specific ADL including simplification, and environmental adaptation such as written cues within the house. These interventions include:

- i) techniques and equipment that compensate for sensorimotor impairment (e.g. developing one-handed dressing techniques, or visually checking on hand grip when pulling trousers up using the weak upper limb);
- ii) the use of written lists and diaries that compensate for impaired organisation and planning skills (e.g. following a shopping list step-by-step, or using a systematic problem-solving procedure during meal preparation).

How the intervention might work

As executive function is a complex process involving a number of different skills, there are many different interventions that aim to work in different ways. Interventions may restore the functional loss (through the stimulation of neuronal growth), compensate for the functional loss (by increasing awareness and teaching ways to cope with the lost cognitive functioning) or adapt to the functional loss (by teaching new strategies to replace the lost functioning). Additionally, interventions may contain a combination of the above categories; for example, restoring attention to enable an individual to use a memory aid.

The results of the polo shirt dressing study by Walker 2004 support the theory that executive dysfunction may have decreased participants' ability to dress due to decreased ability to problem solve the new situation created by upper limb weakness. Interventions may contribute to functional recovery by working to restore an individual's ability to problem solve, form strategies or increase self awareness. Alternatively, they may increase the individual's ability to compensate for executive dysfunction by using strategies or technology to provide feedback or instruction in relation to functional tasks. Furthermore, interventions that are intended to restore or compensate for impaired attention and memory may improve executive function by increasing the accessibility of information to the individual.

Why it is important to do this review

If executive function is directly related to functional ability, a systematic review on the effectiveness of cognitive rehabilitation interventions for improving executive function in people with stroke and brain injury was indicated. Although Cicerone 2005 included executive function as an outcome in their systematic review of studies on cognitive rehabilitation interventions for people with

acquired brain injury, only one study of nine reviewed was a randomised controlled trial (RCT) (Levine 2000). This study, which included 30 participants, investigated the effectiveness of an executive function intervention - goal management training - and reported a positive effect of the intervention. However, the outcome was based on pencil-and-paper tests rather than ADL, and the impact of an executive function intervention on functional ability remains uncertain. Additionally, only studies up to 2002 were included and further studies may have been published since then.

One Cochrane review examined the effectiveness of occupational therapy for cognitive impairment in people with stroke (Hoffmann 2010). Inclusion was limited to interventions that were administered or supervised by an occupational therapist: only one study was included (Carter 1983), which concluded that there was inadequate evidence to determine the effectiveness of occupational therapy on time judgement. Although this was an important review to undertake, it was also important to review the impact of cognitive rehabilitation specifically on executive dysfunction to build on the reviews of attention, unilateral neglect and memory (Bowen 2007; Lincoln 2000), and to include studies from the wider field of neuropsychology.

The intention of this proposed review was to evaluate studies that specifically contain cognitive rehabilitation interventions with executive function outcomes in participants with stroke and non-progressive brain damage.

OBJECTIVES

To determine whether cognitive rehabilitation after stroke or other adult non-progressive acquired brain damage improves executive function.

Specific research questions

In adults with stroke or other non-progressive acquired brain damage with executive dysfunction:

1. is cognitive rehabilitation more effective than no or placebo intervention at improving executive function? No intervention includes participant groups who did not receive any specific cognitive rehabilitation training or functional (sensorimotor) training. Placebo includes interventions that have been determined by the researchers to have no active impact on the aspect of cognition being studied controlling for the social interaction and time the intervention participants spend with the therapist, for example, a repetitive container filling task to work on problem-solving skills;
2. is cognitive rehabilitation more effective than standard care at improving executive function? Standard care includes stroke and brain injury sensorimotor rehabilitation programmes

without specific cognitive rehabilitation components. Sensorimotor interventions are defined as those intended to improve physical function including movement, strength, balance, co-ordination, dexterity sensation and endurance. As most therapeutic interventions contain aspects of cognition training in the form of increasing awareness, improving attention and problem solving, only those that explicitly state the intention of improving an aspect of cognition were defined as cognitive rehabilitation;

3. are some cognitive rehabilitation interventions more effective than other cognitive rehabilitation interventions at improving executive function? This includes comparisons of attention training with goal management training for self monitoring, or electronic memory devices versus mental imagery techniques for improving decision making.

METHODS

Criteria for considering studies for this review

Types of studies

We included RCTs, including randomised cross-over trials (using data from first phase only, where the order of assignment has been determined randomly). Random allocation included trials using computer-generated random numbers, or sequentially numbered opaque sealed envelopes.

Types of participants

We included adults (aged 16 years and older) with executive dysfunction caused by stroke or other acquired non-progressive brain damage. Acquired brain damage includes brain injury, encephalitis, abscess and arteriovenous malformations. We excluded participants with progressive neurological conditions such as a primary diagnosis of dementia, space-occupying lesions and multiple sclerosis.

Types of interventions

Restorative interventions

Interventions that are specifically targeted at restoring components of executive function including goal management training, planning and organisation skills development, problem solving and strategy formation techniques, self awareness and techniques involving self regulation of behaviour, initiation of behaviours and inhibition of prepotent responses.

Compensative interventions

Interventions that compensate for executive function impairment such as use of written strategies and electronic technology, self instruction techniques and feedback methods including mirror and video feedback.

Adaptive interventions

Interventions that train people to use adaptive methods for increasing independence in ADL skills such as the use of techniques and equipment that compensate for sensorimotor impairment, the use of written lists and diaries that compensate for impaired working and prospective memory, and systematic problem-solving procedures.

Comparators include no intervention, standard care (sensorimotor intervention), placebo or other cognitive rehabilitation approaches.

Types of outcome measures

The primary outcome is global executive function, and the secondary outcomes are components of executive function, functional ability in ADL, functional ability in extended ADL, participation in vocational activities, quality of life and social isolation, adverse events and death. We excluded studies without specific executive function outcomes as it would not have been possible to evaluate the intervention effectiveness of executive function.

Primary outcomes

Global executive function

We included executive function assessment batteries that provide a general total score of executive function. Known assessment batteries include:

- Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson 1996);
- Hayling and Brixton Tests (Burgess 1997).

The total scores for these test batteries are calculated from the sum of the scores for the subtests. All raw scores are converted into standardised profile scores and constitute continuous data.

Other assessments specifically designed to measure executive function would be included, with sensitivity analyses to explore the effect of including possible unvalidated assessments.

Secondary outcomes

Executive function component outcomes

We included the following five components of executive function and their related assessments:

1. initiation: assessments include: Hayling Test Part 1 ([Burgess 1997](#)), BADS Rule Shift Part 1 ([Wilson 1996](#));
2. inhibition: assessments include: Hayling Test Part 2 ([Burgess 1997](#)), Tower of Hanoi ([Goel 1995](#));
3. concept formation: assessments include: Brixton Test ([Burgess 1997](#)), Wisconsin Card Sorting Test ([Berg 1948](#));
4. planning: assessments include: Tower of London ([Culbertson 2001](#)), Tower of Toronto ([Saint-Cyr 1992](#)), BADS Zoo Map, Action Program and Modified Six Elements Test ([Wilson 1996](#));
5. flexibility: assessments include: Wisconsin Card Sorting Test, Brixton Test, BADS Rule Shift ([Wilson 1996](#)).

The scoring of the BADS and Hayling and Brixton Test batteries produce raw scores that are converted into standardised profile scores for each subtest. It is, therefore, possible to pool scores from different tests that measure the same component of executive function. In addition, the Wisconsin Card Sorting Test can be scored on the number of achieved categories, number of perseverative responses or the number of perseverative errors, and the Tower Tests are scored on the number of successful completed stages or number of moves required for completion ([Lezak 2004](#)). The data from these tests are continuous, affording the possibility of combining them with specific subtests from the assessment batteries.

Functional ability in activities of daily living

We included the following validated scales: Barthel ADL Index ([Mahoney 1965](#)), Rivermead ADL assessment ([Lincoln 1990](#)), Rivermead Motor Ability scale ([Lincoln 1979](#)), Functional Independence Measure (FIM) ([Keith 1987](#)), Frenchay Activities Index ([Wade 1985](#)), Katz Index of Activities of Daily Living ([Katz 1963](#)), Rehabilitation Activities Profile ([Jelles 1995](#)), and Rankin ADL ([van Swieten 1988](#)). If an individual study reports more than one of these functional ability scales, we planned to use the scale listed earliest in this list.

Functional ability in extended activities of daily living

Nottingham Extended Activities of Daily Living scale ([Nouri 1987](#)), Nottingham Stroke Dressing Assessment ([Walker 1990](#)).

Mood and anxiety level

Hospital Anxiety and Depression Scale (HADS) ([Zigmond 1983](#)).

Participation in vocational activities

Vocational Assessment Protocol ([Thomas 1997](#)).

Quality of life and social isolation

EQ-5D (health-related quality of life scale) ([The EuroQol Group 1990](#)), Quality of Well Being Scale ([Anderson 1989](#)).

Adverse events

Any reported adverse events (excluding death).

Death

If we found any other assessments specifically designed to measure any of the above secondary outcomes we included these with sensitivity analyses to explore the effect of including these possibly unvalidated assessments.

Search methods for identification of studies

See the 'Specialized register' section in the [Cochrane Stroke Group](#) module. We searched for trials in all languages and arranged translation of studies published in languages other than English.

Electronic searches

We searched the trials register of the Cochrane Stroke Group Trials Register (August 2012), the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, August 2012), MEDLINE (1950 to August 2012) ([Appendix 1](#)), EMBASE (1980 to August 2012), CINAHL (1982 to August 2012), PsycINFO (1806 to August 2012) and AMED (1985 to August 2012).

We also searched the following specialist bibliographic databases:

- Proquest Nursing and Allied Health Source (August 2012);
- REHABDATA (www.naric.com/research/rehab/) (August 2012);
- British Nursing Index (May 2011);
- Linguistics and Language Behaviour Abstracts (May 2011);
- OTseeker (www.otseeker.com/) (May 2011);
- Physiotherapy Evidence database (PEDro) (www.pedro.org.au/) (May 2011);
- Chartered Society of Physiotherapy Research Database (May 2011);
- Psychological Database for Brain Impairment Treatment Efficacy (PsycBITE) (www.psycbite.com/) (August 2012);
- PsycEXTRA (www.apa.org/psycextra/) (August 2012);
- PsycARTICLES (www.apa.org/psycarticles/) (August 2012);
- Proquest Dissertations and Theses (PQDT) database (August 2012).

We developed the MEDLINE search strategy with the help of the Cochrane Stroke Group Trials Search Co-ordinator and adapted it for the other databases.

In addition, we searched the following ongoing trials and research registers (May 2011):

- Internet Stroke Center Stroke Trials Registry (www.strokecenter.org/trials/);
- ClinicalTrials.gov (www.clinicaltrials.gov/);

- National Research Register (portal.nihr.ac.uk/Pages/NRRArchiveSearch.aspx);
- UK Clinical Research Network Portfolio Database (public.ukcrn.org.uk/search/);
- Current Controlled Trials (www.controlled-trials.com/) (which also includes the UK Clinical Trials Gateway).

Searching other resources

In an effort to identify further published, unpublished and ongoing trials, we:

- checked reference lists of all relevant articles;
- identified and contacted investigators known to be involved in research in this area;
- used Science Citation Index Cited Reference Search for forward tracking of important articles;
- identified and searched neuropsychology abstracts targeting the following conferences: (USA) National Academy of Neuropsychology, American College of Professional Neuropsychology, American Academy of Clinical Neuropsychology and British Neuropsychological Society (years searched June 2008 to 2010) (last searched June 2010);
- contacted the Cochrane Injuries Group Trials Search Co-ordinator, who provided a list of handsearched journals.

Data collection and analysis

Selection of studies

One review author (CC) screened the titles of the records obtained from the electronic searches and eliminated studies that were clearly not relevant. Two review authors (CC and either AP or TC (half of the studies each)) then independently screened the titles and abstracts of the remaining studies and excluded further studies that were deemed irrelevant. We obtained the full text of the remaining potentially relevant studies and the same three review authors independently selected studies eligible for inclusion based on the inclusion criteria already described. We resolved any disagreements through discussion. We contacted the authors of included studies to request additional data where necessary and to find any other published trials or conference abstracts.

Data extraction and management

We used a predesigned data extraction form to extract data from the studies that met the inclusion criteria. We tested this form on one study with any shortcomings discussed and modifications made. We planned for two review authors (CC and either AP or TC) to perform the extraction independently, and complete the form with data related to the study population, intervention types, intervention comparisons and outcomes. As in the study selection stages, we planned to consult the fourth review author

(BD) if there was uncertainty or disagreement. We documented when available:

1. participant details (including age, gender, place of residence, type of stroke, time since stroke, initial functional ability, co-morbid conditions, premorbid disability);
2. inclusion and exclusion criteria;
3. duration/intensity/frequency of intervention;
4. brief description of the intervention (we classified the intervention using the three groups defined in '[Types of interventions](#)' and documented details including, if relevant, the nature of the intervention, duration and intensity of the intervention, involvement of treating therapist, and qualifications and experience of treating therapist(s));
5. comparison intervention;
6. outcomes.

Assessment of risk of bias in included studies

Two review authors (CC and AP or TC) independently assessed all included trials for potential sources of bias including selection bias, performance bias and attrition bias ([Higgins 2011](#)), with consideration given to methods of participant allocation and allocation concealment, blinding of those assessing and providing interventions to participants, and the completeness of data reporting. We assessed risk of bias by grading the following domains as 'low risk', 'high risk' or 'unclear risk' of bias for each included study, and documented these gradings within the '[Risk of bias](#)' in [Characteristics of included studies](#) tables.

Allocation concealment

Studies with adequate concealment included those that used central randomisation at a site remote from the study; computerised allocation, in which records were in a locked readable file that could be assessed only after entering participant details; the drawing of opaque envelopes. Studies with inadequate concealment included those using an open list or table of random numbers, open computer systems, drawing of non-opaque envelopes. Studies with unclear concealment included those with no or inadequate information in the report.

Blinding

Adequate concealment included studies stating that a masked outcome assessor was used and did not identify any 'unmasking'. Inadequate concealment included studies that did not use a masked outcome assessor, or where the report clearly identified that 'unmasking' occurred during the study. We documented concealment as unclear if a study did not state, or if there was insufficient information to judge whether or not an outcome assessor was masked.

Incomplete outcome data

Studies adequately addressing incomplete outcome data either had: no missing outcome data; missing outcome data that were unlikely to be related to true outcome; missing outcome data that were balanced in numbers across intervention groups, with similar reasons for missing data across groups; a reported effect size (mean difference (MD) or standardised mean difference (SMD)) among missing outcomes that were not enough to have a clinically relevant impact on observed effect size; or missing data that had been inputted using appropriate methods. Studies inadequately addressing incomplete outcome data either had: missing outcome data that were likely to be related to true outcome, with either imbalance in numbers or reasons for missing data across intervention groups; a reported effect size (MD or SMD) among missing outcomes enough to induce clinically relevant bias in the observed effect size; as-treated analysis done with substantial departure of the intervention received from that assigned at randomisation. We documented addressing of incomplete outcome data as unclear if there was insufficient reporting to allow this to be assessed, or if this was not addressed in the report.

Other bias

We assessed a study not to be free of bias if it was assessed to have at least one important risk of bias, such as: a potential source of bias related to the specific study design used, an extreme baseline imbalance, a claim to have been fraudulent, or some other problem. If there was insufficient information, or the information provided was unclear, we documented the risk of other bias as unclear. We produced a 'Risk of bias' summary figure to illustrate the potential biases within each of the included studies.

Measures of treatment effect

We used RevMan 5.1 ([RevMan 2011](#)) to carry out statistical analyses to determine the treatment effect of:

1. cognitive rehabilitation versus no therapy on executive function;
2. cognitive rehabilitation versus placebo on executive function;
3. cognitive rehabilitation versus sensorimotor therapy on executive function;
4. cognitive rehabilitation versus another cognitive rehabilitation approach on executive function.

For dichotomous variables we calculated the treatment effect using a random-effects model and the Mantel-Haenszel method and reported odds ratios (OR) with 95% confidence intervals (CI). For continuous data we calculated the treatment effect using SMDs and 95% CI where different scales were used by different studies for the assessment of the same outcome, and using MDs and 95% CI where studies had used the same method of measuring outcome. We used random-effects models.

Unit of analysis issues

The scores from the executive function assessment batteries produced raw continuous data that were converted to standardised profile scores. The secondary outcomes of executive function components were also continuous data. Secondary outcomes also included functional ability and quality of life, which are commonly measured with ordinal scales. We treated these as continuous data. Where reported outcomes had a scale where a lower value was indicative of a better outcome (e.g. HADS) we multiplied the reported values by -1, so that in all analyses a higher value would be indicative of a better outcome.

If studies reported change values and the baseline value was available, we planned to calculate the value at follow-up (change mean value + baseline value). If studies reported change values and the baseline value was available, we would use these data in meta-analyses, but planned sensitivity analyses to investigate the effect of including these data.

We planned to analyse discharge destination, adverse events and death as dichotomous variables.

Dealing with missing data

We considered that missing data had been adequately addressed if a study had no missing outcome data; outcome data missing at random; missing outcome data that were balanced in numbers across intervention groups, with similar reasons for missing data across groups; a reported effect size (MDs or SMDs) among missing outcomes that were not enough to have a clinically relevant impact on observed effect size; or missing data that had been imputed using appropriate methods.

Studies inadequately addressing incomplete outcome data had outcome data that were likely to be missing not at random; an imbalance in numbers or reasons for missing data across intervention groups; a reported effect size (MDs or SMDs) among missing outcomes enough to induce clinically relevant change in observed effect size; as-treated analysis done with substantial departure of the intervention received from that assigned at randomisation.

We documented the addressing of incomplete outcome data as unclear if there was insufficient reporting to allow this to be assessed, or if this was not addressed in the report.

We attempted to contact the original study authors to obtain missing data.

If an included study did not report (or we could not obtain from a study author) a particular outcome, we did not include that study in the analyses of that outcome.

If an included study had insufficient information reported (e.g. reported means but not standard deviations for the follow-up data) we took logical steps to enter an estimated value. Such steps could include estimating a standard deviation based on a reported standard error, or estimating a follow-up standard deviation based on a baseline value. We undertook sensitivity analyses to investigate the effect of entering estimated values.

Assessment of heterogeneity

We subjected all results to a random-effects meta-analysis to take account of statistical heterogeneity. We determined heterogeneity using the I^2 statistic (I^2 greater than 50% was considered substantial heterogeneity). If heterogeneity was present, we planned to explore and present possible causes.

Assessment of reporting biases

We used the domain-specific risk-of-bias assessment tool in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011a), which replaces rating scales and checklists as the preferred method of assessing the impact of bias.

Data synthesis

Two review authors independently extracted data from the included trials. One review author entered the data into RevMan 5 (RevMan 2011), and the other review author checked the entries. We resolved any disagreements through discussion, with reference to the original study.

Subgroup analysis and investigation of heterogeneity

We planned to conduct subgroup analyses on the conditions of stroke, head injury and encephalitis to determine the effect of cognitive rehabilitation on the executive function of each group. We conducted grouping by intervention, with subgroups that included:

- interventions that aim to:
 - restore executive function;
 - compensate for executive dysfunction and
 - enable the participant to formulate adaptive strategies

to increase independence with ADL.

In addition, we planned to conduct subgroup analyses on clinical presentation including:

- stroke versus brain injury;
- time since stroke onset: less than three months, between three and six months, six months to 12 months, more than 12 months;
- initial level of executive function;
- initial level of function.

Sensitivity analysis

We undertook sensitivity analyses in respect of the inclusion (studies where some participants were not in the defined inclusion criteria of this review) and methodological quality (randomisation process, and blinding of outcome assessor) of the included studies. We planned to include all studies having any ratio of participants

with the defined inclusion criteria, and intended to conduct the sensitivity analysis with studies containing less than 75% of the defined inclusion criteria being removed. We used a criteria list and tick box format to indicate whether we judged that studies met, or did not meet, the predefined methodological quality requirements and explored the effects of including the trials which had an unclear criteria match.

As attrition in studies of cognitive rehabilitation creates a significant source of bias due to the possibility that the most challenging to treat participants are the ones most likely to drop out, we planned to conduct intention-to-treat analyses where we could obtain the incomplete data from participants who dropped out, from the original study authors. Where we could not obtain data, we recorded the possibility of significant bias.

We planned to undertake a further sensitivity analysis on the effect of clinical diagnosis of executive dysfunction versus diagnosis by standardised assessment.

RESULTS

Description of studies

See: [Characteristics of included studies](#); [Characteristics of excluded studies](#); [Characteristics of ongoing studies](#).

Results of the search

The electronic searches yielded 8280 records and, after the initial screening of titles and abstracts by one review author (CC), 8159 irrelevant papers were eliminated. Two review authors (CC and either AP (89 records) or TC (32 records)) independently assessed the titles and abstracts of the remaining 121 studies and selected 51 studies for further assessment. We obtained the full text of the 51 papers and after further assessment, agreed that 21 studies did not meet the selection criteria and excluded them. Details of reasons for exclusion of these studies are listed in the [Characteristics of excluded studies](#) table.

There was insufficient information to reach a decision about the inclusion of seven additional studies (Chen 2011; Dawson 2010; Kim 2008; Matz 2008; Rizkalla 2011; Wood 2012; Zhu 2011) and attempts to contact the authors of these studies are ongoing (see [Characteristics of studies awaiting classification](#)).

Four studies were ongoing (Dawson 2011; de Joode 2008; Hoffman 2009; Singh 2008) (see [Characteristics of ongoing studies](#)).

Thus, 19 studies were eligible for inclusion in the review. [Figure 1](#) shows the study inclusion process.

Figure 1. Study flow diagram.

Included studies

We included 19 studies (907 participants) in this review (Amos 2002; Carter 1980; Cheng 2006; Chung 2007; Cicerone 2008; Dirette 1999; Fong 2009; Goverover 2007; Hewitt 2007; Hu 2003; Jorge 2010; Levine 2000; Lundqvist 2010; Man 2006; O'Connor 2006; Rath 2003; Salazar 2000; Spikman 2010; Westerberg 2007).

We were unable to obtain data for analysis from six of the 19 studies (145 participants). We received responses to requests for means and standard deviations from three study authors indicating that the original data were no longer available (Dirette 1999; Levine 2000; Lundqvist 2010). We were unable to contact the remaining three authors (Amos 2002; Carter 1980; O'Connor 2006). Thus, the data from 13 studies (770 participants) were available to the review.

Two studies included more than two trial groups and we selected the two groups that best represented the cognitive rehabilitation versus no intervention/placebo comparison (Jorge 2010; Man 2006). We excluded the escitalopram group from one study as this intervention is not cognitive rehabilitation (Jorge 2010). The on-line therapists and computer cognitive rehabilitation groups from the other study were excluded to enable the cognitive rehabilitation versus no intervention/placebo comparison to be made (Man 2006). This reduced the inclusion total by a further 96 participants. One study reported 14 participant drop-outs and as a result, only 46 of the original 60 participants were included (Rath 2003). After these group exclusions and drop-outs, a total of 660 participants remained.

We have provided descriptions of the included studies in the [Characteristics of included studies](#) and [Risk of bias in included studies](#) tables.

Study design

Eighteen studies were RCTs and one was a randomised cross-over trial (Lundqvist 2010).

Participants

Data were available for 13 of the studies within meta-analyses (770 participants, 417 traumatic brain injury (TBI), 304 stroke, 49 other acquired brain injury), reducing to 660 participants available for meta-analysis when the non-included groups were removed (395 TBI, 234 stroke, 31 other acquired brain injury).

Classification of treatment approaches

In total, 13 interventions were described in the 19 included studies. Two review authors (CC and AP) classified these into restorative, compensative or adaptive interventions from reading the full papers and they can be found in [Table 1](#). We classified seven of the 13 interventions as restorative and five as compensative interventions. We did not classify any as adaptive interventions. The two review authors agreed on eight classifications, disagreed on two classifications and were uncertain on three interventions. The uncertainty related to standard and intensive neurorehabilitation, which could be considered compensative or restorative depending on the intention within the specific study. This is reflected in these interventions appearing in both restorative and compensative classifications. The disagreements were related to the memory training and directive feedback interventions, which could have been classified into either compensative or adaptive interventions. As both were related less to the training of alternative methods of performing ADL or problem solving, the review authors reached consensus that these should be classified as compensative interventions.

Restorative Interventions (18 studies with 532 participants): the seven interventions include: self awareness training (Cheng 2006; Goverover 2007), intensive neurorehabilitation (Salazar 2000), standard neurorehabilitation including cognitive remediation (Carter 1980; Cicerone 2008; Dirette 1999; Hu 2003; O'Connor 2006; Rath 2003; Salazar 2000; Spikman 2010), problem-solving/goal management training (Fong 2009; Jorge 2010; Levine 2000; Man 2006; O'Connor 2006; Rath 2003; Spikman 2010), autobiographical memory cueing (Hewitt 2007), working memory training (Lundqvist 2010; Westerberg 2007) and verbal feedback (Chung 2007).

Compensative interventions (five studies, 80 participants): the five interventions included: intensive neurorehabilitation (Cicerone 2008); standard neurorehabilitation (Fong 2009); video-feedback (Chung 2007); verbalisation, chunking and pacing (Dirette 1999); and directive feedback (Goverover 2007). A sixth study also included the compensative intervention of inhibition and salience (Amos 2002), but did not state how many participants were allocated to each group.

Adaptive interventions: no intervention fell into this category as most studies focused on general cognition or cognitive components including executive function with no application to function or ADL. The studies with functional applications had a restorative or compensative focus.

The general cognitive interventions of intensive and standard neurorehabilitation could be categorised as restorative or compensative interventions depending on the specific emphasis of the study. These were classified as compensative in the studies by Cicerone 2008 (intervention arm) and Fong 2009 (comparator arm) as they trained participants in the application of residual cognitive abili-

ties in contrast to the other restorative studies that aimed towards improving general cognition.

As the interventions in each trial were categorised into the above classifications, it was possible for each trial to contribute data from different intervention types to more than one comparison. For instance, if a trial compared a restorative cognitive rehabilitation intervention with a compensative control intervention, the data were used in the cognitive rehabilitation versus standard care comparison, the restorative versus other interventions comparison and the compensative versus other interventions comparison.

Training of intervention providers

Two studies (Carter 1980; Rath 2003) indicated that the intervention providers were trained in the study intervention. Four studies (Fong 2009; Lundqvist 2010; Salazar 2000; Spikman 2010) provided the professional level of the intervention providers (experienced brain injury occupational therapists, certified coaches, board-certified physiatrist and experienced rehabilitation therapist or neuropsychologist, respectively) but did not indicate that specific training was provided in the interventions. Eight studies stated only the identity of the intervention providers, which included therapists, trainers, research assistants and psychologists (Chung 2007; Cicerone 2008; Goverover 2007; Hewitt 2007; Levine 2000; Man 2006; O'Connor 2006; Westerberg 2007). Four studies did not provide details of the intervention providers (Amos 2002; Cheng 2006; Dirette 1999; Jorge 2010). The details of any training, professional qualifications or identity of the intervention providers from one study (Hu 2003) was not included in the study translation from Chinese to English. Only the study by Rath 2003 provided details of the consistency checking of the intervention through training and video-feedback.

Outcome classification

Two review authors determined which executive function components related to each outcome measure. This is a task that was open to interpretation as many of the outcome measures in the included studies can relate to more than one executive function component. Some components were related to specific outcomes in the protocol but decisions were made with regard to outcome measures that were not listed in the protocol. A neuropsychologist, Professor James Jackson from Vanderbilt University in Tennessee, contributed to the determination of which executive function component was related to each outcome measure, providing additional expert opinion to support these classifications (see Table 2).

Comparisons

Table 1 displays the interventions and comparisons investigated in each study. The 19 included studies fall into three groups of comparisons.

Cognitive rehabilitation versus standard care

We included three studies (134 participants) in this comparison (Carter 1980; Hu 2003; Levine 2000). None reported our primary outcome of global executive function. Two studies included measures of components of executive function; including concept formation (Neurobehavioural Cognitive Status Examination: Hu 2003); and planning (proof reading: Levine 2000). Two studies included measures of working memory (Digit Span Test: Carter 1980; Room Layout: Levine 2000). One study included a measure of ADL (Barthel Index: Hu 2003). However, it was not possible to conduct a meta-analysis as only data from Hu 2003 were eligible for inclusion. Both Carter 1980 and Levine 2000 only provided measures of change and did not report means or standard deviations.

Cognitive rehabilitation versus no treatment or placebo

We included six studies (333 participants) in this comparison (Amos 2002; Hewitt 2007; Jorge 2010; Lundqvist 2010; Man 2006; Westerberg 2007). None reported our primary outcome of global executive function. All six studies included measures of components of executive function, including concept formation (Wisconsin Card Sorting Test: Amos 2002; the Category Test: Man 2006; Raven's Progressive Matrices: Westerberg 2007), planning (the Everyday Descriptions Task: Hewitt 2007), and flexibility (the Stroop Test: Jorge 2010; Westerberg 2007). Three studies included measures of working memory (Trail Making Test: Jorge 2010; Paced Auditory Serial Attention Test (PASAT): Lundqvist 2010; Westerberg 2007). One study included a measure of ADL (Canadian Occupational Performance Measure: Lundqvist 2010), one study included a measure of extended ADL (Lawton Instrumental Activities of Daily Living Scale: Man 2006), and one study included a quality of life measure (EQ-5: Lundqvist 2010). Data from Hewitt 2007, Jorge 2010, Man 2006 and Westerberg 2007 were suitable for inclusion within the meta-analyses; Amos 2002 did not report how many participants were in each group and Lundqvist 2010 did not report separate results for both groups before the cross-over, only providing the PASAT scores for the non-intervention group at this stage. The main intervention being studied by Jorge 2010 was the antidepressant escitalopram. As this is not cognitive rehabilitation, the second intervention group, which received problem-solving therapy, was compared against the group receiving a placebo antidepressant. The experimental groups of the remaining six studies were all compared against a group receiving no intervention.

Experimental cognitive rehabilitation versus standard cognitive rehabilitation approach

We included 10 studies (448 participants) in this comparison (Cheng 2006; Chung 2007; Cicerone 2008; Dirette 1999; Fong 2009; Goverover 2007; O'Connor 2006; Rath 2003; Salazar 2000;

Spikman 2010). Two studies reported the primary outcome of global executive function (BADs: Chung 2007; Spikman 2010). All 10 studies included measures of components of executive function; including inhibition (Hayling Tests: Chung 2007), concept formation (Self Awareness of Deficits Interview: Cheng 2006; Brixton Test: Chung 2007; Booklet Category Test: Cicerone 2008; Raven's Progressive Matrices: Fong 2009; Assessment of Awareness of Disability: Goverover 2007; Wisconsin Card Sorting Test: Rath 2003; Salazar 2000); planning (Key Search: Fong 2009; Test of Planning: O'Connor 2006; Tower of London Test: Spikman 2010), and flexibility (Stroop Test: Spikman 2010). Four studies included measures of working memory (Trail Making Test: Cicerone 2008; Spikman 2010; PASAT: Dirette 1999; Salazar 2000). Three studies included measures of ADL (FIM: Cheng 2006; Adapted Nottingham Stroke Dressing Assessment: Chung 2007; Assessment of Motor and Process Skills: Goverover 2007). One study included a measure of extended ADL (Lawton Instrumental Activities of Daily Living Scale: Cheng 2006). Two studies included measures of quality of life (Perceived Quality of Life Scale: Cicerone 2008; Quality of Life after Brain Injury: Spikman 2010). Three studies included measures of participation in vocational activities (Community Integration Questionnaire: Cicerone 2008; Goverover 2007; Vocational Integration Scale: Cicerone 2008; Role Resumption List: Spikman 2010). Data from Cheng 2006, Chung 2007, Cicerone 2008, Fong 2009, Goverover 2007, Rath 2003, Salazar 2000 and Spikman 2010 were available for in-

clusion in meta-analyses; Dirette 1999 did not report means and standard deviations and O'Connor 2006 was a conference abstract only and did not report numeric results.

In addition to these three comparisons, we carried out subgroup analysis to explore the effect of the type of cognitive rehabilitation (restorative or compensative).

Excluded studies

We excluded 70 studies based on assessment of the 121 abstracts that initially appeared to meet the inclusion criteria. Exclusions were mainly due to three reasons: (1) not an RCT (N = 62), (2) no executive function outcome or no separable executive function outcome from situations where a comprehensive cognitive outcome measure was used (N = 7), and (3) the interventions were not cognitive rehabilitation (N = 1). We excluded a further 21 studies after consideration of the remaining 51 studies bringing the total number of excluded studies to 90. These 21 studies and reasons for exclusion are listed in the [Characteristics of excluded studies](#) table.

A further four studies were ongoing (Dawson 2011; de Joode 2008; Hoffman 2009; Singh 2008), and are detailed in the [Characteristics of ongoing studies](#) table.

Risk of bias in included studies

See 'Risk of bias' summary table ([Figure 2](#)).

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Allocation concealment (selection bias)	Blinding (performance bias and detection bias)	Incomplete outcome data (attrition bias)	Other bias
Amos 2002	+	?	+	?
Carter 1980	?	?	-	-
Cheng 2006	?	+	+	+
Chung 2007	+	+	-	-
Cicerone 2008	+	+	?	+
Dirette 1999	?	+	+	+
Fong 2009	?	?	+	?
Goverover 2007	?	?	+	+
Hewitt 2007	?	+	+	?
Hu 2003	?	+	-	-
Jorge 2010	?	+	+	-
Levine 2000	?	?	-	?
Lundqvist 2010	?	?	+	+
Man 2006	?	+	+	?
O'Connor 2006	?	?	?	?
Rath 2003	?	?	?	?
Salazar 2000	?	?	+	+
Spikman 2010	?	+	+	?
Westerberg 2007	+	-	+	-

Allocation

Four of the 19 included studies included sufficient information to assess that allocation had been concealed (Chung 2007; Cicerone 2008; Goverover 2007; Salazar 2000). There was insufficient information for an adequate assessment of concealment in the remaining 15 studies.

Blinding

Six studies reported sufficient information to determine that the assessors were blinded to group allocation (Chung 2007; Cicerone 2008; Dirette 1999; Hewitt 2007; Jorge 2010; Spikman 2010). Although the Role Resumption Checklist and Dysexecutive Questionnaire were reported not to have masked assessment in the study by Spikman 2010, the neuropsychological measures included in the meta-analyses were administered by a blinded assessor. The assessors were not blinded in three studies. In the study by Amos 2002, the intervention and assessments were administered at the same time in the study, making blinding not possible. It was not possible to blind assessors in the study by Salazar 2000 as participants were allocated to a home intervention or hospital intervention, and assessors were aware of group allocation in the study by Westerberg 2007. There was insufficient information to determine whether the assessors were blinded in the remaining 10 studies.

Incomplete outcome data

Eleven studies reported either no drop-outs or accounted for participant drop-outs in analyses. Five studies did not account for the drop-outs (Carter 1980; Hu 2003; Man 2006; Rath 2003; Westerberg 2007) and there was insufficient information in the studies by Cicerone 2008 and O'Connor 2006 to determine whether data from participants had been adequately accounted for. Data were not sufficiently accounted for in the study by Chung 2007 where assessment data were not complete due to participants with aphasia being unable to complete language-dependent assessments.

Other potential sources of bias

The study by Westerberg 2007 was assessed as having no other sources of bias. Two studies were determined to be at risk of bias: the same therapist provided the interventions to both groups in the study by Goverover 2007; the interventions were directly related to the outcome measure in the study by Hewitt 2007 where there was the possibility that the intervention training could be considered to be coaching the tasks required to improve performance on the outcome measure. One study (Chung 2007) had a very small sample size. There was insufficient information in the remaining

studies to determine whether there was a risk of any other sources of bias.

Effects of interventions

We included data from 13 studies within meta-analyses, presented within three main comparisons:

1. cognitive rehabilitation versus standard care (one study, 86 participants);
 2. cognitive rehabilitation versus no treatment or placebo (four studies, 184 participants);
 3. experimental cognitive rehabilitation versus standard cognitive rehabilitation (eight studies, 404 participants).
- In addition, we combined data from eight of the 13 studies (282 participants) within a subgroup analysis to explore the effect of the type of cognitive rehabilitation delivered.

1. Cognitive rehabilitation versus standard care

(Studies included: Hu 2003)

1.1 Concept formation

Data from one study (Hu 2003) (86 participants) showed that there was a statistically significant effect in favour of cognitive rehabilitation when compared with sensorimotor therapy (MD - 0.43, 95% CI -0.76 to -0.10) for the concept formation outcome (Analysis 1.1).

1.2 Activities of daily living

Data from one study (Hu 2003) (86 participants) showed that there was a statistically significant effect in favour of cognitive rehabilitation when compared with sensorimotor therapy (MD - 28.28, 95% CI -33.50 to -23.06) for the ADL outcome (Analysis 1.2).

2. Cognitive rehabilitation versus no treatment or placebo

(Studies included in meta-analyses: Hewitt 2007; Jorge 2010; Man 2006; Westerberg 2007). We carried out sensitivity analyses where appropriate but these are not shown on the forest plots.

2.1 Components of executive function

2.1.1 Concept formation

Data from two studies (Man 2006; Westerberg 2007) (68 participants) showed that there was no statistically significant effect of cognitive rehabilitation compared with no treatment (SMD -0.03, 95% CI -0.52 to 0.45) for the concept formation outcome (Analysis 2.1). We carried out a sensitivity analysis by removing one study (Westerberg 2007), which clinically diagnosed participants with executive dysfunction before inclusion, leaving Man 2006 (50 participants) (SMD 0.09, 95% CI -0.47 to 0.66). The results from this one study continued to show that there was no statistically significant effect of cognitive rehabilitation compared with sensorimotor therapy on the outcome of concept formation.

2.1.2 Planning

Data from one study (Hewitt 2007) (30 participants) showed that there was no statistically significant effect of cognitive rehabilitation compared with no treatment (SMD -0.39, 95% CI -1.11 to 0.33) for the planning outcome (Analysis 2.1).

2.1.3 Flexibility

Data from two studies (Jorge 2010; Westerberg 2007) (104 participants) showed that there was no statistically significant effect of cognitive rehabilitation compared with no treatment (SMD -0.11, 95% CI -0.90 to 0.67) (Analysis 2.1). There was substantial heterogeneity ($\text{Chi}^2 = 2.46$, degrees of freedom (df) = 1, P value = 0.12, $I^2 = 59\%$) in this meta-analysis and differences between the two studies were apparent. Jorge 2010 included participants up to three months' poststroke and Westerberg 2007 included participants between 12 and 36 months poststroke. In addition, Jorge 2010 included a comparison of problem solving with drug placebo, as the main focus of the research was the effect of an antidepressant on executive function. Westerberg 2007 compared a computer working memory intervention with no treatment and was, therefore, not subject to a possible placebo effect.

2.2 Working memory

Data from two studies (Jorge 2010; Westerberg 2007) (104 participants) showed that there was no statistically significant effect of cognitive rehabilitation compared with no treatment (SMD -0.10, 95% CI -1.39 to 1.18) on the outcome of working memory (Analysis 2.2). As with the flexibility outcome, there was substantial heterogeneity ($\text{Chi}^2 = 5.93$, df = 1, P value = 0.01, $I^2 = 83\%$).

2.3 Activities of daily living

Data from one study (Man 2006) (50 participants) showed that there was no statistically significant effect of cognitive rehabilitation compared with no treatment (MD 0.07, 95% CI -3.09 to 3.23) on the outcome of extended ADL (Analysis 2.3).

3. Experimental cognitive rehabilitation versus standard cognitive rehabilitation

(Studies included in meta-analyses: Cheng 2006; Chung 2007; Cicerone 2008; Fong 2009; Goverover 2007; Rath 2003; Salazar 2000; Spikman 2010) We carried out sensitivity analyses where appropriate but these are not shown on the forest plots.

3.1 Global executive function

Data from two studies (Chung 2007; Spikman 2010) (82 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (video-feedback; goal management training) compared with standard cognitive rehabilitation approaches (verbal-feedback; computer cognitive training) (SMD -0.41, 95% CI -0.85 to 0.03) on the outcome of global executive function (Analysis 3.1). We carried out a sensitivity analysis by removing one study (Spikman 2010), which clinically diagnosed participants with executive dysfunction before inclusion, leaving Chung 2007 (seven participants) (SMD -0.08, 95% CI -1.58 to 1.42). The results from this one study continued to show that there was no statistically significant effect of experimental cognitive rehabilitation compared with standard cognitive rehabilitation on global executive function.

3.2 Components of executive function

3.2.1 Inhibition

Data from one study (Chung 2007) (seven participants) showed that there was no statistically significant effect of an experimental cognitive rehabilitation approach (video-feedback) compared with a standard cognitive rehabilitation approach (verbal-feedback) (SMD -0.83, 95% CI -2.93 to 1.28) on the outcome of inhibition (Analysis 3.2).

3.2.2 Concept formation

Data from seven studies (329 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (self awareness training, video-feedback, intensive neurorehabilitation, problem-solving training, group cognitive rehabilitation) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation; corrective feedback) (SMD -0.16, 95% CI -0.44 to 0.11) on the outcome of concept formation (Cheng 2006; Chung 2007; Cicerone 2008; Fong 2009; Goverover 2007; Rath 2003; Salazar 2000) (Analysis 3.2).

We carried out a sensitivity analysis by removing all studies that did not have evidence of allocation concealment, leaving two studies (Chung 2007; Cicerone 2008) (75 participants) (SMD -0.06, 95% CI -0.40 to 0.52) and removing all studies that did not

have evidence of outcome assessor blinding, leaving three studies (Cheng 2006; Chung 2007; Cicerone 2008) (96 participants) (SMD -0.43, 95% CI -1.41 to 0.55). The meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of concept formation.

We conducted a second sensitivity analysis by removing the studies that diagnosed participants with executive dysfunction using a standardised assessment before inclusion (Chung 2007; Rath 2003; Salazar 2000), leaving Cheng 2006, Cicerone 2008, Fong 2009 and Goverover 2007 (142 participants) (SMD -0.23, 95% CI -0.78 to 0.31). The results from this meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of concept formation.

Only one of the seven studies included participants with stroke only (Chung 2007). The remaining six studies included either participants with mixed brain injury causes or TBI only. Therefore, it was possible to conduct a subgroup analysis on the studies that included only participants with TBI, including Cheng 2006, Cicerone 2008, Rath 2003 and Salazar 2000 (269 participants) (SMD -0.23, 95% CI -0.65 to 0.18). We found no statistically significant effect in relation to this subgroup.

3.2.3 Planning

Data from two studies (108 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (problem-solving training, goal management training) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation; computer cognitive training) (SMD -0.30, 95% CI -0.68 to 0.08) on the outcome of planning (Fong 2009; Spikman 2010) (Analysis 3.2).

3.2.4 Flexibility

Data from one study (75 participants) showed that there was no statistically significant effect of an experimental cognitive rehabilitation approach (goal management training) compared with a standard cognitive rehabilitation approach (computer cognitive training) (MD -0.39, 95% CI -0.85 to 0.07) on the outcome of flexibility (Spikman 2010) (Analysis 3.2).

3.3 Working memory

Data from three studies (263 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (intensive neurorehabilitation, group cognitive rehabilitation, goal management training) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation, corrective feedback, computer cognitive rehabilitation)

(SMD -0.12, 95% CI -0.36 to 0.13) on the outcome of working memory (Cicerone 2008; Salazar 2000; Spikman 2010) (Analysis 3.3).

We carried out a sensitivity analysis by removing all studies that did not have evidence of allocation concealment, leaving two studies (Cicerone 2008; Spikman 2010) (143 participants) (SMD -0.18, 95% CI -0.56 to 0.21). The meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of working memory. Sensitivity analysis only including studies that used a standardised assessment of executive dysfunction resulted in the same two studies being included (Cicerone 2008; Spikman 2010).

3.4 Activities of daily living

3.4.1 Activities of daily living

Data from three studies (48 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (self awareness training, video-feedback) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation, corrective feedback) (SMD -0.52 95% CI -1.11 to 0.06) on the outcome of ADL (Cheng 2006; Chung 2007; Goverover 2007) (Analysis 3.4).

We carried out a sensitivity analysis by removing all studies that did not have evidence of outcome assessor blinding, leaving two studies (Cheng 2006; Chung 2007) (28 participants) (SMD -0.35, 95% CI -1.11 to 0.40). The meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of ADL.

We conducted a second sensitivity analysis by removing a study (Chung 2007), which diagnosed participants with executive dysfunction using a standardised assessment before inclusion, leaving Cheng 2006 and Goverover 2007 (41 participants) (SMD -0.50, 95% CI -1.12 to 0.13). The results from this meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of ADL.

3.4.2 Extended activities of daily living

Data from one study (Cheng 2006) (21 participants) showed that there was no statistically significant effect of an experimental cognitive rehabilitation approach (self awareness training) compared with a standard cognitive rehabilitation approach (standard cognitive rehabilitation) (SMD -0.49, 95% CI -1.36 to 0.38) on the outcome of extended ADL (Analysis 3.4).

3.5 Quality of life

Data from two studies (143 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (intensive neurorehabilitation, goal management training) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation, computer cognitive training) (SMD -0.11, 95% CI -0.44 to 0.22) on the outcome of quality of life (Cicerone 2008; Spikman 2010) (Analysis 3.5).

3.6 Vocational activities

Continuous data from three studies (163 participants) showed that there was no statistically significant effect of experimental cognitive rehabilitation approaches (intensive neurorehabilitation, self awareness training, goal management training) compared with standard cognitive rehabilitation approaches (standard cognitive rehabilitation, corrective feedback, computer cognitive training) (SMD -0.02, 95% CI -0.56 to 0.51) on the outcome of vocation (Cicerone 2008; Goverover 2007; Spikman 2010) (Analysis 3.6). We carried out a sensitivity analysis by removing all studies that did not have evidence of allocation concealment and outcome assessor blinding, leaving two studies (Cicerone 2008; Spikman 2010) (143 participants) (SMD -0.02, 95% CI -0.56 to 0.51). The meta-analysis continued to show that there was no statistically significant effect of experimental cognitive rehabilitation approaches compared with standard cognitive rehabilitation approaches on the outcome of vocation. A subgroup analysis to explore the effect of including only participants with TBI included the same two studies with the same result (Cicerone 2008; Spikman 2010). Dichotomous data from one study (68 participants) showed that there was a statistically significant effect of an experimental approach (intensive neurorehabilitation) compared with a standard cognitive rehabilitation approach (standard cognitive rehabilitation) (OR 0.29, 95% CI 0.10 to 0.85) on the outcome of vocation (Cicerone 2008) (Analysis 3.7).

4. Type of cognitive rehabilitation (subgroup analyses)

We carried out subgroup analyses to explore the type of cognitive rehabilitation (restorative or compensative). We included data from four studies that compared a restorative cognitive intervention with a compensative cognitive intervention (Chung 2007; Cicerone 2008; Fong 2009; Goverover 2007); and three studies that compared a restorative cognitive intervention with no intervention (Jorge 2010; Man 2006; Westerberg 2007). We carried out analyses for the outcomes of concept formation, working memory and ADL.

4.1 Concept formation

Data from six studies (196 participants) showed that there was no statistically significant effect of restorative interventions compared

with other interventions, including compensative (SMD -0.04, 95% CI -0.32 to 0.24) on the outcome of concept formation (Chung 2007; Cicerone 2008; Fong 2009; Goverover 2007; Man 2006; Westerberg 2007).

4.2 Working memory

Data from three studies (172 participants) showed that there was no statistically significant effect of restorative interventions compared with other interventions, including compensative (SMD -0.00, 95% CI -0.62 to 0.61) on the outcome of working memory (Cicerone 2008; Jorge 2010; Westerberg 2007).

4.3 Activities of daily living

Data from two studies (27 participants) showed that there was no statistically significant effect of restorative interventions compared with compensative interventions (SMD -0.19, 95% CI -1.60 to 1.22) for functional ADL (Chung 2007; Goverover 2007).

DISCUSSION

Summary of main results

We found 19 studies (907 randomised participants, 496 TBI, 344 stroke, 67 other acquired brain injury). Data were available to potentially include 13 of the studies within meta-analyses (770 participants, 417 TBI, 304 stroke, 49 other acquired brain injury), with 660 participants included in treatment groups relevant for inclusion in this review. Studies related to three key comparisons: (1) cognitive rehabilitation versus sensorimotor meta-analyses (one study, 86 participants), (2) cognitive rehabilitation versus no intervention or placebo meta-analyses (four studies, 184 participants) and (3) experimental cognitive rehabilitation versus standard cognitive rehabilitation meta-analyses (eight studies, 404 participants). However, there was insufficient high-quality evidence to reach any generalised conclusions about the effect of cognitive rehabilitation on any outcomes, for all comparisons. In summary:

- **global executive function**, our primary outcome of interest, was only reported by two studies (82 participants), both of which compared an experimental cognitive rehabilitation with a standard cognitive rehabilitation approach. There is, therefore, insufficient evidence to reach generalised conclusions about the effect of cognitive rehabilitation on global executive function;
- **components of executive function** were reported by 13 studies and data incorporated into meta-analyses for the three comparisons. We found a statistically significant benefit for cognitive rehabilitation, as compared with sensorimotor therapy. However, this analysis only included one study for which there was a likelihood of bias from the uncertainty of whether

allocation was concealed and drop-outs unaccounted for. We found no other statistically significant effects for any comparisons for any components of executive function. There is, therefore, currently no high-quality evidence that cognitive rehabilitation has a beneficial (or detrimental) effect on components of executive function;

- **working memory** was reported by five studies and incorporated into meta-analyses for the three comparisons. We found no statistically significant effects for cognitive rehabilitation in any of the comparisons for working memory. There is, therefore, currently no high-quality evidence that cognitive rehabilitation has a beneficial (or detrimental) effect on working memory;

- **ADL** were reported by five studies and data incorporated into meta-analyses for three comparisons. We found a statistically significant benefit for cognitive rehabilitation, as compared with sensorimotor therapy. However, this analysis only included one study for which there was a likelihood of bias from the uncertainty of whether allocation was concealed and drop-outs unaccounted for. Extended ADL were reported by two studies and incorporated into three comparisons. We found no other statistically significant effects for any comparisons for measures of ADL or extended ADL. There is, therefore, currently no high-quality evidence that cognitive rehabilitation has a beneficial (or detrimental) effect on ADL or extended ADL;

- **quality of life** was reported by two studies and data incorporated into two comparisons. We found no statistically significant effects for cognitive rehabilitation in either of the comparisons for quality of life. There is, therefore, currently no high-quality evidence that cognitive rehabilitation has a beneficial (or detrimental) effect on quality of life;

- **vocational activities** were reported by three studies and incorporated into two comparisons. We found a statistically significant effect for experimental cognitive rehabilitation versus standard cognitive rehabilitation. However, this analysis only included one study where the outcome was based on the dichotomous variable of whether the participants were engaged in purposeful vocational activities or not, and the meta-analysis of three studies showed no statistically significant effect of cognitive rehabilitation on vocation as a continuous measure. There is, therefore, currently no high-quality evidence that cognitive rehabilitation has a beneficial (or detrimental) effect on vocational activities;

- **adverse events or deaths** were not reported by any included studies.

Overall completeness and applicability of evidence

Study inclusion

We used a thorough search process to identify all published studies, and we attempted to contact authors for information to determine whether to include their studies in this review. Thus, there is only a small possibility that we have missed any studies (published and unpublished). Our inability to obtain data from six relevant studies (145 participants) introduces a potential bias into this review.

Of the 19 included studies, the data were not available from six studies (145 participants: 79 TBI, 40 stroke, 18 others and eight healthy volunteers). The interventions evaluated in these excluded studies included goal management training (Levine 2000; O'Connor 2006), cognitive remediation (Carter 1980), computer working memory training (Lundqvist 2010) and strategies for information management including inhibition/salience (Amos 2002) and verbalisation, chunking and pacing (Dirette 1999). Of these six studies, two were eligible for the cognitive rehabilitation versus standard care comparison (Carter 1980; Levine 2000), two studies were eligible for the cognitive rehabilitation versus no intervention or placebo (Amos 2002; Lundqvist 2010) and two studies were eligible for the experimental cognitive rehabilitation versus standard cognitive rehabilitation comparison (Dirette 1999; O'Connor 2006). Inability to include data from these studies is a potential risk of bias within this review.

Executive function consists of a number of different processes and for the purpose of comparing studies with similar outcomes, we found it necessary to separate the comparisons into these different processes. Although we included 13 studies within the meta-analyses, the need to separate the comparisons decreased the number of studies in each meta-analysis, with most only including two studies, resulting in small comparisons from which it was inappropriate to draw generalised conclusions.

The conclusions that can be drawn from this review are, therefore, substantially limited by the quantity of available data.

Comparison interventions

Of the 13 studies we included in the meta-analyses, the majority of the studies (eight of the 13) were included in the experimental cognitive rehabilitation versus standard cognitive rehabilitation comparison. If the standard cognitive interventions are effective, there is a possibility of a reduction in the postintervention differences between the study groups. This comparison is not able to answer the key question relating to whether cognitive rehabilitation is effective (when compared with no intervention or placebo), limiting the clinical applicability of the results from this comparison.

Quality of the evidence

The overall methodological reporting of the studies was poor, with only two studies (Chung 2007; Cicerone 2008) within the meta-analyses reporting both allocation concealment and assessor blinding. However, one of these studies (Chung 2007) had a very small

sample size (seven participants) and was at risk of attrition bias due to two participants being unable to complete the verbal executive function outcome measures.

Only four out of 18 meta-analyses from the three main comparisons included three or more studies ([Analysis 3.2](#); [Analysis 3.3](#), [Analysis 3.4](#); [Analysis 3.6](#)), with the majority only including two studies.

The sample sizes of the studies ranged from seven to 129 ([Jorge 2010](#)). There were small sample sizes in most studies, with 11 studies having sample sizes of 33 and below. Only three studies had sample sizes in excess of 100 participants ([Jorge 2010](#); [Man 2006](#); [Salazar 2000](#)).

The combination of small, poor-quality studies and low numbers of studies within the meta-analyses reduces the ability to generalise from the results of this review.

Potential biases in the review process

Publication bias

The 13 studies included in meta-analyses published data from outcomes consistent with the outcomes stated in the [Methods](#) sections. As executive function consists of several subcomponents, of which there could be a choice of several outcome measures, it was not possible for us to determine the nature of publication bias resulting from incomplete reporting of results.

Executive function definition

Although we agreed on the components of executive function through consensus for this review, we accept that there is no universally agreed definition of executive function and our list of executive function components may differ from other theorists, researchers and clinicians.

Intervention categorisation

We undertook the process of categorising the interventions as restorative, compensative or adaptive and attempted to avoid the introduction of bias by agreeing the independent classifications of two authors. We accept that, despite two review authors (AP and CC) agreeing the categorisation, a number of interventions not described in the protocol could potentially fall into the restorative or adaptive category. Where an intervention is intended to teach participants a strategy for problem solving, if we viewed the strategy as being a different method for problem solving than the usual process, we would consider it compensative. However, if we viewed the strategy as being the usual sequence broken into component parts, then we would consider this restorative as recovery would restore the prior problem-solving ability. Using two review

authors to categorise the interventions was intended to reduce bias, but we accept that it would not eliminate it.

Outcome classification

We attempted to reduce the introduction of bias through the assistance of an expert neuropsychologist who helped to categorise the outcomes. We also reduced the potential for bias by deciding on the executive function components prior to data analysis.

Outcome measure selection

Many of the studies used multiple outcome measures, of which, several could be considered to be related to the same executive function components. When a choice of outcome measures was available, we selected the one listed in the protocol. If the outcome measure options were not in the protocol, we selected the more established one over one which was designed for the particular study (see [Table 3](#)). To reduce bias, this process was undertaken prior to data analysis. However, we accept that the multiple options of outcome measurement selection could lead to different measures being selected. In addition, as there is no universal definition of executive function, and no agreed list of the components, there may be opinion differences on which components of executive function the outcome measures relate to.

Document translation

One study ([Hu 2003](#)) had Chinese text with an English abstract. An independent interpreter translated key parts of the text to enable data extraction. We assessed potential bias but we accept that other sources of bias may exist of which we are unaware as the full study was not translated.

Agreements and disagreements with other studies or reviews

Two reviews ([Cicerone 2011](#); [Zoccolotti 2011](#)) concluded that some interventions for executive dysfunction demonstrated effectiveness from RCTs. The first reviewed the self awareness studies that have been included in this review ([Cheng 2006](#); [Goverover 2007](#)) and the autobiographical cueing planning intervention by [Hewitt 2007](#), which is also included in this review. The authors recommended that metacognitive techniques (including self awareness) should be employed in cognitive rehabilitation. The second review included three different studies in the executive function intervention section. They included [Wilson 2001](#), [Powell 2002](#) and [Levine 2000](#). The study by [Levine 2000](#) was included in this review, but one study ([Wilson 2001](#)) did not include an executive function outcome measure and the other study by [Powell 2002](#) did not include a cognitive rehabilitation intervention, and consequently neither was eligible for this review. The authors recommended the use of the Neuropage intervention as 'A' (based on

well-designed randomised trials with low chance of bias) and gave a 'B' recommendation for the problem-solving approach. Both reviews were narrative reviews and did not conduct meta-analyses. In this review, we have not found sufficient high-quality evidence to recommend any one cognitive rehabilitation intervention clearly.

AUTHORS' CONCLUSIONS

Implications for practice

We found insufficient high-quality evidence to either support or refute the hypothesis that cognitive rehabilitation interventions improve executive function.

Implications for research

The findings of this review support the following implications.

1. Further RCTs, with low risk of bias, are required to determine the effect of cognitive rehabilitation interventions compared with no intervention, placebo or sensorimotor interventions. We consider it necessary to prioritise these comparisons over the experimental cognitive rehabilitation versus standard cognitive rehabilitation comparison, as there is less potential for both aspects of the latter comparison to have a significant effect on executive function. Three ongoing studies (see [Characteristics of ongoing studies](#)) may represent trials of this type ([Dawson 2011](#); [de Joode 2008](#); [Singh 2008](#)), as they include comparisons of cognitive rehabilitation with conventional therapy, care as usual, and sham interventions, respectively.
2. Research to determine any correlation between executive function outcome measures and ADL is required. The ongoing study by [Dawson 2011](#) may contribute to this knowledge base by including a patient-centred outcome measure (Canadian Occupational Performance Measure) for ADL and the executive function measure (Dysexecutive Questionnaire). However, it is likely that more research will still be required.
3. Well-conducted RCTs that determine the effect of cognitive rehabilitation interventions on specific components of executive

function are essential. As executive function is multicomponential and people with brain injury may present with differing profiles of executive dysfunction, it will be valuable to determine the effect of interventions that specifically target the impaired components of executive function.

4. Research leading to the development of tools that measure executive function during ADL is essential.

This review has implications for the design of key methodological features of future trials. In particular, future trialists should consider: ensuring that the cognitive rehabilitation and control intervention are comparable in duration and frequency; outcome measures should include assessments of components of executive function relevant to the component that is targeted by an intervention; inclusion criteria based on time since brain injury event; use of validated measures of executive function as a selection criteria and an outcome measure; ensuring that sample size is based on power calculations; adequately addressing potential sources of bias; the training, profession and qualifications of the person delivering both the intervention and control; providing data in a format suitable for subgroup analysis according to brain injury categories (including stroke and TBI).

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Amos 2002

Methods	RCT Method of randomisation not documented	
Participants	24 participants with acquired brain injury (6 stroke, 16 traumatic brain injury and 2 others not specified) and 8 healthy control participants Group 1: n = 8 Group 2: n = 8 Group 3: n = 8 Group 4: n = 8 Age 20-55 years, able to communicate and provide consent Attention difficulty determined by neuropsychological profile and behavioural disturbance	
Interventions	Group 1: no intervention Group 2: external inhibition: participants instructed to ignore specific features (compensative) Group 3: salience: participants provided with information on the similarities of specific features (compensative) Group 4: healthy control (restorative)	
Outcomes	Wisconsin Card Sorting Test for concept formation	
Notes	The healthy controls were selected from relatives of the participants The mean age of the sample was 35.71 (9.77) years with 11.83 (2.01) years in education. Separate group demographic data not given so unable to determine group differences	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	A non-involved person drew lots to allocate participants into the 3 brain injury groups
Blinding (performance bias and detection bias) All outcomes	Unclear risk	No details provided on assessor blinding
Incomplete outcome data (attrition bias) All outcomes	Low risk	No drop-outs were reported
Other bias	Unclear risk	The data of 1 participant with severe perseveration was removed from the study as the results were very different from the others

Carter 1980

Methods	RCT Method of randomisation not documented
Participants	14 participants with stroke and 4 non-stroke participants Group 1: n = 10 Group 2: n = 8 Mean age 70.8 years (group 1) and 73 years (group 2) Cognitive impairment was determined by a neuropsychological test with 5 domains, 1 of which was working memory from Digit Span Test
Interventions	Group 1: 30-40 minute cognitive remediation sessions (restorative), 3 times per week for 4 weeks Group 2: no cognitive intervention. Continued with standard physiotherapy, occupational therapy and speech therapy (restorative)
Outcomes	Digit Span Test for working memory
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Allocation concealment not documented
Blinding (performance bias and detection bias) All outcomes	Unclear risk	Not clear if assessors were blinded but rehabilitation staff were unaware of group allocation
Incomplete outcome data (attrition bias) All outcomes	High risk	The 18 participants were reduced from an initial 37. Data from participants who dropped out or refused the post-test were not used in the analysis
Other bias	High risk	The control group had a higher initial score than the experimental group. The control group did not have comparable time in placebo or control intervention so extra intervention time may be the cause of any improvement

Cheng 2006

Methods	RCT Randomisation according to admission sequence
Participants	21 participants with TBI Group 1: n = 11

	Group 2: n = 10 Stable, alert and able to communicate Self awareness impairment diagnosed with SADI	
Interventions	Group 1: restorative intervention of self awareness training incorporating concrete feed-back, education on the condition and self prediction and goal-setting training (11.7 session/week for 4 weeks) Group 2: control intervention incorporating group ADL training, motor skills training in preparation for ADL and cognitive training (restorative) (11.6 sessions/week for 4 weeks)	
Outcomes	SADI (lower score = improvement) FIM Lawton Instrumental Activities of Daily Living Scale	
Notes	Control group participants were an average of 3.2 years older than the experimental group. 2 experimental group participants had received tertiary education compared with 0 participants in the control group. Control group acute stay was 4.7 weeks and experimental group was 6 weeks. Rehabilitation stay for the respective groups was 10 weeks and 7.5 weeks	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	It is unclear from the study text whether allocation was concealed
Blinding (performance bias and detection bias) All outcomes	Low risk	“Scoring was primarily conducted by a therapist who was not involved in the programme implementation and blinded to the grouping of participants,” which indicates low risk but “primarily conducted” may imply that not all assessments were conducted by this therapist. The study was single-blind as the participants were not blinded to their allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	Complete data on 21 participants were presented
Other bias	Low risk	No other sources of bias identified

Chung 2007

Methods	RCT Computer programme randomisation
Participants	7 participants with stroke: 4 females, 3 males, 2 left hemisphere strokes and 5 right hemisphere strokes Group 1: n = 3 Group 2: n = 4 First stroke, age range 55-95 years, able to provide informed consent, adequate visual acuity and sitting balance, Barthel score of 5 or less for the dressing component Executive dysfunction determined by BADS and Hayling and Brixton Tests
Interventions	Group 1: verbal feedback after upper body dressing task (compensative) Group 2: video-feedback and verbal feedback after upper body dressing task (compensative) 6 x 30-minute sessions over 2 weeks
Outcomes	BADS, Hayling and Brixton Tests, adapted Nottingham Stroke Dressing Assessment
Notes	The experimental group time mean time since stroke was 27 days (SD = 7.87) compared with 7.33 days (SD = 3.51) for the control group

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	Computer programme used to randomly assign to group with allocation concealed in sealed envelopes
Blinding (performance bias and detection bias) All outcomes	Low risk	The assessor was blinded at pre and post assessment
Incomplete outcome data (attrition bias) All outcomes	High risk	All participants completed the study but only 5 out of 7 participants were able to complete the verbal executive function outcome measures
Other bias	High risk	Small sample size without statistical power

Cicerone 2008

Methods	RCT Method of randomisation included the use of a "web-based statistical calculation page (www.statpages.org) to allocate 48 participants per condition" Randomisation occurred in blocked multiples of 4 and were stratified according to clinical or community referrals
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Participants	68 participants with TBI at least 3 months' postinjury Group 1: n = 34 Group 2: n = 34 Adequate language and comprehension to participate in verbal group sessions, judged to require at least 4 months of rehabilitation, capable of attending 3 sessions/week, able to give informed consent Participants were not assessed for executive dysfunction	
Interventions	Group 1: standard neurorehabilitation (restorative intervention) 15 hours/week for 15 weeks of individual, discipline specific therapies Group 2: intensive neurorehabilitation (compensative intervention) 15 hours/week for 15 weeks of intensive cognitive rehabilitation emphasising the integration of cognitive, interpersonal and functional interventions and including training in self appraisal, prediction, self monitoring and self evaluation, which were not included in standard neurorehabilitation	
Outcomes	Trail Making Test-B for working memory Booklet Category Test for concept formation Vocational Integration Scale Perceived Quality of Life Scale	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	Allocation was concealed in opaque envelopes
Blinding (performance bias and detection bias) All outcomes	Low risk	The therapists were not blinded but were informed that it was uncertain which intervention was potentially more effective. Outcome measures were conducted by a blinded research assistant
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	All existing data analysed. 4 participants did not complete the standard neurorehabilitation protocol and 2 participants did not complete the intensive cognitive rehabilitation protocol. 2 participants in each group were lost to follow-up
Other bias	Low risk	

Dirette 1999

Methods	RCT Participants were matched to a severity level (mild, moderate, severe) and randomised within these categories. Method of randomisation was not stated
Participants	30 participants 2-12 months post acquired brain injury including 2 with stroke Group 1: n = 15 Group 2: n = 15 Participants were aged 21-56 years, with mean age of 38 years All participants were pretested with computer tests including the PASAT
Interventions	Group 1: 6 x 1-hour weekly sessions training the strategies of verbalisation, chunking and pacing (compensative) Group 2: 6 x 1-hour sessions of computer activities (restorative)
Outcomes	PASAT for working memory
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Allocation concealment was not documented
Blinding (performance bias and detection bias) All outcomes	Low risk	The assessor was blinded to the participants' groups
Incomplete outcome data (attrition bias) All outcomes	Low risk	No drop-outs were reported
Other bias	Low risk	

Fong 2009

Methods	Matched-pairs RCT. Each participant was matched to another participant of similar age, gender, diagnosis, educational level, time of injury and severity of injury. Following matching, a member of each pair was randomised into the control or experimental group. Method of randomisation not documented
Participants	33 participants including 9 with stroke, 18 with TBI and 6 with other acquired brain injury. All were documented as having problem-solving difficulties Group 1: n = 16 Group 2: n = 17 Participants were aged 18-55 years, literate, had at least 6 years' primary education and were able to comprehend written instructions and do simple arithmetic Cognitive impairment was assessed using the Rancho Los Amigos Scale and Behavioural Memory Test

Interventions	Group 1: metacomponential problem-solving training programme (restorative) involving the training of the primary metacomponents of problem solving which are: defining the problem, representing the problem, planning problem-solving strategies, monitoring selected strategies, and evaluating outcomes. Participants received standard cognitive rehabilitation and 22 sessions over 15 weeks with 45 minutes of metacomponential skills training and 30 minutes of computer training to apply the problem-solving skills learned Group 2: standard cognitive rehabilitation programme (compensative) comprising residual function use for adaptive function	
Outcomes	Six Elements Test for problem solving Key Search Tests for everyday problem solving Social Problem-Solving Video Measure Means-Ends Problem Solving Measure Raven's Progressive Matrices Metacomponential Interview	
Notes	The experimental group also received standard neurorehabilitation and the duration and frequency of sessions was stated. However, the duration and frequency of the standard neurorehabilitation group was not stated and it is unclear whether the experimental group received more time in training	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Details were provided for the matching procedure but did not describe how participants were randomised and whether allocation was concealed
Blinding (performance bias and detection bias) All outcomes	Unclear risk	No details were provided
Incomplete outcome data (attrition bias) All outcomes	Low risk	Although the study reported participant attrition, this occurred after the postintervention data collection period and the existing data applies to all 33 participants
Other bias	Unclear risk	Duration and frequency of control intervention was not stated

Goverover 2007

Methods	RCT Method of randomisation not documented
Participants	20 participants with acquired brain injury including 12 with TBI and 8 with aneurysm Group 1: n = 10 Group 2: n = 10 Participants' aged 18-55 years; medically stable living in the community and orientated to time, person and the community; independent in basic ADL and identified as having a self awareness problem by their therapist
Interventions	Group 1: self awareness training with instrumental ADL (restorative) Group 2: conventional training of instrumental ADL including corrective feedback by a therapist (restorative) Each group received 2 sessions per week for 3 weeks of 45 minutes/session
Outcomes	Assessment of Awareness of Disability for task-specific awareness and general awareness Self-Regulation Skills Interview for metacognition Assessment of Motor and Process Skills for instrumental ADL Community Integration Questionnaire for home and social integration and productive activities
Notes	The table of brain injury type for the experimental group exceeded 100%, which may be an error but does not affect the overall analysis as the brain injury subgroups do not have separable data

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Method of randomisation and allocation concealment not documented
Blinding (performance bias and detection bias) All outcomes	Unclear risk	Although the participants were blinded to their group allocation, the study does not state whether the assessors were blinded
Incomplete outcome data (attrition bias) All outcomes	Low risk	Complete data were presented for all study participants
Other bias	Low risk	

Hewitt 2007

Methods	RCT Participants were randomised according to a predetermined allocation sequence
Participants	30 severe TBI with post-traumatic amnesia of longer than 24 hours, 16-64 years of age, able to understand and read English, 1 year or more since injury Group 1: n = 15

Hewitt 2007 (Continued)

	Group 2: n = 15 Executive dysfunction diagnosed by the Hayling and Brixton Tests and the Modified Six Elements Test	
Interventions	Group 1: general conversation (control) Group 2: Autobiographical Episodic Memory Cueing Procedure (restorative) Each group received 30 minutes' intervention	
Outcomes	Everyday Descriptions Task for planning	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Concealment of allocation was not documented in the study text
Blinding (performance bias and detection bias) All outcomes	Low risk	The assessor was blinded to group allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	There were no drop-outs as the 1 intervention session and assessments were undertaken during the same session
Other bias	Unclear risk	The intervention is very close to the outcome measure with the potential for the equivalent of direct training for outcome measure performance improvement

Hu 2003

Methods	RCT Randomisation by computer program	
Participants	86 inpatients with stroke Group 1: n = 44 Group 2: n = 42	
Interventions	Group 1: 45-minute session/day, 5 days/week of cognitive rehabilitation including the use of cards, use of practical objects, self programmed computer software and transition to ADL (restorative) Group 2: medicine, occupational therapy and physiotherapy (restorative)	
Outcomes	Neurobehavioural Cognitive Status Examination for general cognition but with executive function subcomponents, Barthel Index	

Hu 2003 (Continued)

Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Allocation concealment not documented
Blinding (performance bias and detection bias) All outcomes	Low risk	Assessor was blinded
Incomplete outcome data (attrition bias) All outcomes	High risk	No data for the 8 participants who dropped out
Other bias	High risk	If the cognitive rehabilitation sessions were in addition to standard therapies, the extra intervention may have had the positive effect rather than the content per se

Jorge 2010

Methods	RCT Randomisation by computer program and non-involved individual	
Participants	129 participants with 3 months of stroke Group 1: n = 45 Group 2: n = 43 Group 3: n = 41 Participants aged 50-90 years old, literate, no depression, and able to comprehend and make decisions	
Interventions	Group 1: placebo drug (no intervention) Group 2: escitalopram (not cognitive rehabilitation) Group 3: problem-solving training (restorative)	
Outcomes	Trail Making Test Part A and B for working memory Stroop Test for flexibility	
Notes	Trial includes FIM baseline measurement but does not give final outcome measurement Comparison used will be problem-solving therapy versus drug placebo	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement

Allocation concealment (selection bias)	Unclear risk	The individual conducting the allocation was non-involved but no indication of blinding
Blinding (performance bias and detection bias) All outcomes	Low risk	Assessments carried out by blinded technician
Incomplete outcome data (attrition bias) All outcomes	Low risk	Intention-to-treat and regression analyses conducted for drop-outs
Other bias	High risk	Problem-solving group was older than the other groups and had lower initial outcomes

Levine 2000

Methods	RCT Method of randomisation not stated
Participants	30 participants, 3-4 years post TBI, ranging from mild to severe Group 1: n = 15 Group 2: n = 15 All participants living independently but classified as good recovery (n = 24), or moderate disability (n = 6)
Interventions	Group 1: goal management training (restorative) Group 2: motor skills training (control) Each group received 1 training session of 1-hour duration
Outcomes	Proofreading, Grouping and Room Layout for planning
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Not documented in the text of the study
Blinding (performance bias and detection bias) All outcomes	Unclear risk	Not documented in the text of the study
Incomplete outcome data (attrition bias) All outcomes	High risk	The data for 1 participant was missing from each group with no explanation provided

Levine 2000 (Continued)

Other bias	Unclear risk	The study was a part of a larger study of which no details are available but may have confounding variables
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Lundqvist 2010

Methods	Randomised controlled cross-over trial Randomisation undertaken using "drawing of lots"
Participants	21 participants with acquired brain injury (1 TBI, 11 stroke, 5 encephalitis, 2 tumour and 2 subarachnoid haemorrhage), aged 20-65 years, passed postacute state (time since injury/illness 1 year) Group 1: n = 10 Group 2: n = 11 Self reported working memory impairments and a significantly impaired working memory index compared with the index for verbal comprehension and/or index for perceptual organisation or a working memory index less than 80 using the Wechsler Adult Intelligence Scale III, and reported motivation for training
Interventions	Group 1: 45- to 60-minute sessions, 5 days/week for 5 weeks of computer working memory training with special feedback given once/week in addition to continuous statistical data provided on the computer screen (restorative) Group 2: no intervention (precross-over control) Groups crossed over after this first block of training and Group 2 received the training while Group 1 had no intervention
Outcomes	PASAT for working memory
Notes	Additional outcomes included the EQ-5D and Canadian Occupational Performance Measure but these were only administered after both groups received training

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Allocation undertaken through drawing of lots but the study did not state who undertook this task and how it was undertaken
Blinding (performance bias and detection bias) All outcomes	Unclear risk	No documentation of whether assessors, intervention providers or participants were blinded
Incomplete outcome data (attrition bias) All outcomes	Low risk	No drop-outs at the end of the first phase of the cross-over trial
Other bias	Low risk	

Man 2006

Methods	RCT The method of randomisation was not described	
Participants	103 participants (55 stroke, 13 TBI, 35 others), 18-55 years old, acquired brain injury at or within 6 months, adequate attention for 45-minute session, able to write with a pen in English or Chinese, fair verbal comprehension, medically stable, underwent rehabilitation, no psychiatric problems or mental handicap, not computer phobic Group 1: n = 28 Group 2: n = 30 Group 3: n = 25 Group 4: n = 20 Executive dysfunction was not diagnosed but lower level cognition was assessed and participants were included if they demonstrated lower cognitive abilities	
Interventions	Group 1: problem-solving computer training (restorative) Group 2: therapist training (restorative) Group 3: online training with a therapist (restorative) Group 4: control Each of the intervention groups received 20 x 45-minute weekly sessions. The control condition was not described	
Outcomes	Problem Solving Questionnaire Category Test of Halstead-Reitan Neuropsychological Test Battery for concept formation Lawton Instrumental Activities of Daily Living Index	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Lots were drawn in 2 stages for randomisation but concealment was not stated
Blinding (performance bias and detection bias) All outcomes	Low risk	Participants and assessors were blinded
Incomplete outcome data (attrition bias) All outcomes	Low risk	There were no drop-outs
Other bias	Unclear risk	Control group had no placebo, therefore, contact alone may still be contributing to improvements

O'Connor 2006

Methods	RCT Method of randomisation not stated	
Participants	14 participants (7 stroke, 4 TBI, 3 others) Group 1: n = 6 Group 2: n = 8 Information from abstract. No other details available	
Interventions	Group 1: goal management training including self instruction strategies, self monitoring exercises, simulated real-life tasks and homework (restorative) Group 2: control intervention including support, information provision, group activities and homework Each of the intervention groups received 20 x 45-minute weekly sessions. The control condition was not described	
Outcomes	Test of planning (not described in the abstract)	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Not described in abstract
Blinding (performance bias and detection bias) All outcomes	Unclear risk	Not described in abstract
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not described in abstract
Other bias	Unclear risk	Not clear as only abstract available

Rath 2003

Methods	RCT Method of randomisation not stated	
Participants	60 participants with TBI, at least 1 year post injury with higher level cognitive function including 1 hour sustained attention, ability to take organised notes, give and receive feedback, adequate social skills to relate to others and state cognitive strengths and weaknesses Group 1: n = 32 Group 2: n = 28 Method of diagnosing higher level cognitive dysfunction: Wisconsin Card Sorting Test (Perseverative Response Score), Problem-Solving Inventory, Problem Solving Questionnaire, Problem Solving Roleplay Test	

Rath 2003 (Continued)

Interventions	Group 1: group problem-solving intervention (restorative), 24 sessions of 1 x 2-hour group session/week Group 2: conventional cognitive remediation (restorative), 2-3 hours/week of remediation and psychosocial components
Outcomes	Wisconsin Card Sorting Test for concept formation Problem Solving Inventory (self appraisal) Problem Solving Questionnaire (clear thinking and emotional self regulation) Problem Solving Role Playing Test (response to face-to-face interpersonal problem)
Notes	A 6-month follow-up for Group 1 (n = 18) and Group 2 (n = 13) was conducted

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	No information provided in study text of allocation concealment
Blinding (performance bias and detection bias) All outcomes	Unclear risk	No information provided on assessors, participants or those providing the interventions being blinded
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	6-month follow-up data had 14 and 15 participants drop out for Groups 1 and 2, respectively. No statistical methods were used to determine the impact of these drop-outs
Other bias	Unclear risk	Baseline group characteristics were not given

Salazar 2000

Methods	RCT Blocked randomisation used variable-sized blocks "to prevent investigators from guessing the code"
Participants	120 participants with moderate-to-severe closed head injury (Glasgow Coma Scale of 13 or less) or post-traumatic amnesia lasting longer than 24 hours or CT/MRI scan showing contusion or haemorrhage, minimum Rancho Los Amigos score of 7, active duty military member, independent ambulation, home setting with at least 1 responsible adult and no prior severe brain injury Group 1: n = 67 Group 2; n = 53 No specific assessment for executive function was undertaken. A Mini Mental Test was administered to all participants

Interventions	Group 1: in-hospital based daily cognitive and physical exercise regimen with specific group based planning and organisation, cognitive skills, work rehabilitation and work placements (restorative). No specific times stated Group 2: physical and cognitive exercises and weekly 30-minute telephone call from a psychiatric nurse (restorative). At 2 months, 76% reported 30 minutes/day on these exercises	
Outcomes	PASAT Wisconsin Card Sorting Test Outcomes were measured 12 months after study commencement	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	This was not addressed in the text of the study. It is not known whether allocation was concealed or not
Blinding (performance bias and detection bias) All outcomes	Unclear risk	It was not possible to blind treating therapists or participants due to them either being in hospital or at home. "Although treatments could not be blinded and study participation was recorded in the patients' chart, the specificity of Army regulations and the various levels of review helped protect against systematic biases in duty fitness determinations"
Incomplete outcome data (attrition bias) All outcomes	Low risk	Intention-to-treat analysis was undertaken for 7 participants in Group 1 and 6 participants in Group 2
Other bias	Low risk	

Spikman 2010

Methods	<p>RCT</p> <p>Randomisation was carried out by a non-involved individual who blindly allocated each balanced group of 4 to experimental or control conditions</p>	
Participants	<p>75 participants with TBI, 3 months' minimum post onset, aged 17-70 years living at home, outpatient with post-injury executive dysfunction from self report or observation</p> <p>Group 1: n = 38</p> <p>Group 2: n = 37</p> <p>Method of diagnosing executive dysfunction: BADS and DEX</p>	

Spikman 2010 (Continued)

Interventions	Group 1: multifaceted executive function training including goal management and problem-solving training (restorative) Group 2: computerised cognitive training package of several repetitive exercises (restorative) Both groups received 20-24 x 1-hour sessions, 2 times/week over 3 months
Outcomes	BADS for general executive function Trail Making Test for working memory Stroop Test for flexibility Tower of London Test for planning Treatment Goal Attainment DEX EOS Role Resumption List Quality of Life after Brain Injury
Notes	This was a multicentre trial with outcomes measured immediately after treatment and at 6 months

Risk of bias

Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Unclear risk	Randomisation was by drawing lots of 4 which could mean that every fourth allocation was unblinded. A non-involved blinded individual to randomise blinded participants was used
Blinding (performance bias and detection bias) All outcomes	Low risk	The assessor was blinded with the exception of the therapist-rated DEX and EOS
Incomplete outcome data (attrition bias) All outcomes	Low risk	3 participants were lost from the experimental group and 1 was lost from the control group at the 6-month assessment but all data were used
Other bias	Unclear risk	Unclear time allocated to each group

Westerberg 2007

Methods	RCT Participants were randomised by selection of sealed envelopes
Participants	18 participants, 12-36 months post stroke, scan confirmed stroke, aged 30-65 years (vocational age), daily personal computer access with Internet at home, and self reported attention deficits

	Group 1: n = 9 Group 2: n = 9	
Interventions	Group 1: control (no training) Group 2: computer working memory training (restorative), 40 minutes 5 days/week for 5 weeks	
Outcomes	PASAT for working memory Digit Span (auditory working memory) Span board (visuo-spatial working memory) Stroop Test for flexibility Raven's Progressive Matrices for concept formation	
Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Allocation concealment (selection bias)	Low risk	Allocation was concealed in sealed envelopes, which were prepared by individuals who were unrelated to the study
Blinding (performance bias and detection bias) All outcomes	High risk	Assessors and participants were not blinded to group allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	There were no drop-outs and complete data were analysed for all participants
Other bias	High risk	The passive control group does not rule out therapist contact being the cause of any changes rather than the intervention content

ADL: activities of daily living
 BADS: Behavioural Assessment of Dysexecutive Syndrome
 CT: computerised tomography
 DEX: Dysexecutive Questionnaire
 EOS: Executive Observation Scale
 FIM: Functional Independence Measure
 MRI: magnetic resonance imaging
 PASAT: Paced Auditory Serial Addition Test
 RCT: randomised controlled trial
 SADI: Self Awareness of Deficits Interview
 SD: standard deviation
 TBI: traumatic brain injury

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Bushnik 2010	No executive function outcome
Chen 1997	Not an RCT but a matched design
Chen 2006	Study does not include separable executive function outcome
Evans 2009	No executive function outcome. Attention is the focus of this study
Fasotti 2007	The intervention was found to be cognitive behavioural therapy and not cognitive rehabilitation
Hayashi 2012	No executive function outcome
Jo 2009	Transcranial direct current stimulation is not defined as cognitive rehabilitation
Lam 2006	No executive function outcome. The main outcome was the use of an underground transport system
Levine 2011	Study is a controlled trial with no randomisation
Lundqvist 2010a	Not an RCT
McEwen 2011	Ongoing randomised trial with no executive function outcome
Novakovic-Agopian 2011	Study was a non-randomised cross-over trial
Oftinowski 2006	Not an RCT
Pachalska 2012	Study was a controlled trial with no randomisation
Pereira 2012	Not an RCT
Polatajko 2012	Study does not include an executive function outcome
Rios 2011	Not an RCT
Skidmore 2011	Study was a controlled trial with no randomisation
Tam 2004	The outcome was memory and not executive function
Tang 2005	Not fully randomised, use of matched block design. No executive function outcome
von Cramon 1991	Not an RCT. Allocation to group based on admission sequence

RCT: randomised controlled trial

Characteristics of studies awaiting assessment *[ordered by study ID]*

Chen 2011

Methods	Randomised cross-over trial
Participants	12 participants (9 with traumatic brain injury, 1 leukoencephalopathy, 1 right temporal-parietal tumour resection, 1 basal ganglia stroke), 6 months to 6 years post event, 24-63 years old, 5 male, 7 female Group 1: n = 5 Group 2: n = 7
Interventions	Group 1: goals training Group 2: education
Outcomes	Attention and executive function domain score comprising: design and verbal fluency switching, Trails B and Stroop Test
Notes	Z change scores only reported. Baseline and postintervention data not included in the article

Dawson 2010

Methods	Experimental, controlled trial, randomisation uncertain
Participants	12 community dwelling adults, at least 1 year post-traumatic brain injury Group 1: n = 6 (3 male, 3 female), mean age 31.7 years Group 2: n = 6 (3 male, 3 female), mean age 30.0 years
Interventions	Group 1: problem-solving training Group 2: waiting list control
Outcomes	Self and significant other report of performance change of goals
Notes	Abstract only available and is unclear as to whether an executive function outcome was included

Kim 2008

Methods	Controlled trial, randomisation uncertain from abstract
Participants	50 participants with stroke Group 1: n = 30 Group 2: n = 20
Interventions	Group 1: Rehacom computerised cognitive training 30 minutes, 5 times/week for 4 weeks Group 2: intervention not stated
Outcomes	Computerised Neuropsychological Test Lowenstein Occupational Therapy Cognitive Assessment

Kim 2008 (Continued)

Notes	Abstract only available
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Matz 2008

Methods	RCT
Participants	32 participants with first lacunar stroke. Numbers allocated to experimental and control groups are not stated on the abstract
Interventions	Group 1: cognitive training sessions for 3 months Group 2: standard care
Outcomes	Unspecified neuropsychological test battery to assess memory, speed of cognitive processing, executive functions, attention and visuo-spatial functions
Notes	Abstract only available

Rizkalla 2011

Methods	RCT
Participants	18 participants with acute stroke Group 1: n = 9 Group 2: n = 9
Interventions	Group 1: visuospatial/visuomotor training programme 20 hours over 4 weeks Group 2: control
Outcomes	Trails B for working memory Disability Assessment for Dementia for ADL
Notes	Abstract only available. Control intervention not stated in abstract

Wood 2012

Methods	RCT
Participants	Total number of participants uncertain from abstract Group 1: n = 21 (acquired brain injury)
Interventions	Group 1: goal management training with implementation intentions for prospective memory Group 2: goal management training with visual imagery (control)
Outcomes	JAAM virtual reality task for executive function with a measure for prospective memory
Notes	Abstract only available

Zhu 2011

Methods	Experimental controlled trial, randomisation uncertain from abstract
Participants	46 participants with brain injury Group 1: n = 26 Group 2: n = 20
Interventions	Group 1: traditional rehabilitation training 30-40 minutes twice/day and 30 minutes' computer-assisted training twice/day for 5 weeks Group 2: traditional rehabilitation training 30-40 minutes twice/day for 5 weeks
Outcomes	Neurobehavioural Cognitive Status Examination Clock drawing test Reasoning ability
Notes	Abstract only available

ADL: activities of daily living

JAAM: a novel office-based virtual-reality task

RCT: randomised controlled trial

Characteristics of ongoing studies [ordered by study ID]**Dawson 2011**

Trial name or title	Managing Dysexecutive Syndrome
Methods	RCT
Participants	Adults with moderate-to-severe traumatic brain injury or complicated mild traumatic brain injury
Interventions	Group 1: novel behavioural intervention Group 2: conventional rehabilitation Both interventions 1 hour, 2 times/week for 15 sessions
Outcomes	Canadian Occupational Performance Measure for functional performance, instrumental ADL profile and the DEX for executive function
Starting date	March 2012
Contact information	Deidre D Dawson, ddawson@rotman-baycrest.on.ca Alison M Douglas, adaouglas@rotman-baycrest.on.ca
Notes	

de Joode 2008

Trial name or title	"NeuroCue". A Randomised Controlled Study into the Use of an Electronic Cognitive Aid in Patients with Acquired Brain Injury
Methods	RCT
Participants	<ol style="list-style-type: none"> 1. Participants with acquired brain injury in either a subacute or a chronic phase 2. Participants are referred for cognitive rehabilitation 3. Aged 18-75 years 4. Adequate comprehension of the Dutch language 5. Experienced problems in daily life functioning as a consequence of brain damage; insight into cognitive deficits; sufficient IQ level to benefit from treatment according to the rehabilitation physician or psychologist
Interventions	The experimental group will receive the PDA for a period of 16 weeks, the control group will receive 'care-as-usual', defined as calendar training or other types of strategy training to cope with their cognitive disabilities. Both groups will receive an equal amount of therapy time, namely 15-20 hours in total
Outcomes	<p>Primary</p> <ol style="list-style-type: none"> 1. The efficiency on target behaviours measured with an interview 2. Subjective cognitive problems in daily life, self efficacy, and social and instrumental activities 3. Experiences of participants and carers with the use of the PDA 4. The effectiveness of device usage <p>Secondary</p> <ol style="list-style-type: none"> 1. Levels of distress and depression for the user 2. Levels of distress, strain and depression for the carers 3. Quality of life for participants and close family members
Starting date	1 May 2008
Contact information	Trial website: www.np.unimaas.nl/neurocue
Notes	

Hoffman 2009

Trial name or title	Evaluation of Brief Interventions for Enhancing Early Emotional Adjustment Following Stroke: a Pilot Randomised Controlled Trial
Methods	RCT comparing a self management intervention with a coping skills intervention and a control group
Participants	Participants with stroke
Interventions	<p>8 sessions of self management intervention conducted by an occupational therapist will include: (1) provision and reinforcement of individualised written information; (2) activities to learn problem-solving skills, perform functional tasks and adjust to life poststroke</p> <p>8 sessions of coping skills intervention conducted by a clinical psychology trainee will include: (1) cognitive and behavioural exercises to prepare individuals for discharge and to adjust postdischarge including psychoeducation, self monitoring, graduated activity participation and cognitive restructuring</p> <p>Standard care including medical assessment and treatment, nursing care, assessment and/or treatment from</p>

Hoffman 2009 (Continued)

	allied health staff, discharge planning and any information or education associated with this treatment
Outcomes	<ol style="list-style-type: none"> 1. Presence or absence, and severity of anxiety and depressive symptoms as determined by structured interview based on the Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition) and HADS 2. Functional performance as measured by the modified BI and the Nottingham Extended ADL Scale 3. Cognitive appraisal ability as measured by the Stress Appraisal Coping Measure 4. Stroke knowledge as measured by the Knowledge of Stroke Questionnaire 5. Quality of life as measured by the Stroke and Aphasia Quality of Life Scale 6. Treatment expectations as measured by the Treatment Expectations Scale 7. Self awareness of deficits as measured by the Self-Perceptions in Rehabilitation Questionnaire
Starting date	15 October 2009
Contact information	www.anzctr.org.au/
Notes	

Singh 2008

Trial name or title	The Study of Mental Activity and Regular Training for the Prevention of Cognitive Decline in at Risk Individuals: the SMART Trial
Methods	RCT
Participants	Participants with stroke
Interventions	<ol style="list-style-type: none"> 1. Cognitive training: the SMART trial suite of cognitive training exercises aimed at computer-based multi-modal, multi-domain and taskload-graded training in the areas of memory, executive function, attention and speed of information processing 2. Combined cognitive and exercise combination: cognitive and exercise training on the same day (90-minute sessions), 3 sessions/week for 26 weeks 3. Resistance training intervention: the PRT will be conducted 3 days/week, 45 minutes/session, for 26 weeks 4. Sham cognitive and sham exercise control groups: in these groups, participants will receive ineffective versions of cognitive and physical exercise programmes, 3 sessions/week for 26 weeks <p>Participants randomised to: (1) cognitive training + sham PRT; (2) PRT + sham cognitive training; (3) cognitive training + PRT; (4) sham cognitive + sham PRT</p>
Outcomes	<p>Primary outcomes</p> <ol style="list-style-type: none"> 1. Cognitive performance: involves assessing attention, memory, language, problem solving, and speed through clinician and participant-administered questionnaires: Mini-Mental State Examination, Clinical Dementia Rating Scale, Alzheimer's Disease Assessment Scale-cognitive subscale, Matrices and Similarities, Trail Making Test, Symbol Digit Modalities Test, Logical Memory, Benton Visual Retention Test, Category fluency, Controlled Oral Word Association Test, Memory Awareness Rating Scale <p>Secondary outcomes</p> <ol style="list-style-type: none"> 1. functional independence assessed by the Participant and Informant Bayer-Activities of Daily Living questionnaire 2. Psychological outcomes including, Short Form 36, Quality of Life Scale, Life Satisfaction Scale, Scale of Psychological Well-being, and Depression Anxiety and Stress Scale

Singh 2008 (Continued)

	3. Physical testing including: exercise stress test, exercise capacity, body composition, blood pressure (ankle-brachial index, orthostatic blood pressure), muscle strength, balance, gait speed, nutritional biochemistry, insulin resistance and glucose homeostasis, genetic polymorphism, cortisol stress response, inflammatory biomarkers, habitual levels of physical activity and sleep 4. Self reported size and satisfaction of social support, and community health services utilisation
Starting date	1 September 2009
Contact information	www.strokecenter.org/trials/
Notes	

ADL: activities of daily living

BI: Barthel Index

DEX: Dysexecutive Questionnaire

HADS: Hospital Anxiety and Depression Scale

PDA: Personal Digital Assistant

PRT: progressive resistance training

RCT: randomised controlled trial

DATA AND ANALYSES

Comparison 1. Cognitive rehabilitation versus standard care

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Components of executive function	1		Mean Difference (IV, Random, 95% CI)	Subtotals only
1.1 Concept formation	1	86	Mean Difference (IV, Random, 95% CI)	-0.43 [-0.76, -0.10]
2 Activities of daily living	1	86	Mean Difference (IV, Random, 95% CI)	-28.28 [-33.50, -23.06]

Comparison 2. Cognitive rehabilitation versus no treatment

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Components of executive function	4		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
1.1 Concept formation	2	68	Std. Mean Difference (IV, Random, 95% CI)	-0.03 [-0.52, 0.45]
1.2 Planning	1	30	Std. Mean Difference (IV, Random, 95% CI)	-0.39 [-1.11, 0.33]
1.3 Flexibility	2	104	Std. Mean Difference (IV, Random, 95% CI)	-0.11 [-0.90, 0.67]
2 Working memory	2	104	Std. Mean Difference (IV, Random, 95% CI)	-0.10 [-1.39, 1.18]
3 Activities of daily living	1		Mean Difference (IV, Random, 95% CI)	Subtotals only
3.1 Extended activities of daily living	1	50	Mean Difference (IV, Random, 95% CI)	0.07 [-3.09, 3.23]

Comparison 3. Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Global executive function	2	82	Std. Mean Difference (IV, Random, 95% CI)	-0.41 [-0.85, 0.03]
2 Components of executive function	8		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
2.1 Inhibition	1	5	Std. Mean Difference (IV, Random, 95% CI)	-0.83 [-2.93, 1.28]
2.2 Concept formation	7	313	Std. Mean Difference (IV, Random, 95% CI)	-0.16 [-0.44, 0.11]
2.3 Planning	2	108	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.68, 0.08]
2.4 Flexibility	1	75	Std. Mean Difference (IV, Random, 95% CI)	-0.39 [-0.85, 0.07]
3 Working memory	3	263	Std. Mean Difference (IV, Random, 95% CI)	-0.12 [-0.36, 0.13]
4 Activities of daily living	3		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
4.1 Activities of daily living	3	48	Std. Mean Difference (IV, Random, 95% CI)	-0.52 [-1.11, 0.06]
4.2 Extended activities of daily living	1	21	Std. Mean Difference (IV, Random, 95% CI)	-0.49 [-1.36, 0.38]

5 Quality of life	2	143	Std. Mean Difference (IV, Random, 95% CI)	-0.11 [-0.44, 0.22]
6 Vocational activities	3	163	Std. Mean Difference (IV, Random, 95% CI)	-0.00 [-0.37, 0.37]
7 Vocational activities (dichotomous)	1	68	Odds Ratio (M-H, Random, 95% CI)	0.29 [0.10, 0.85]

Comparison 4. Type of cognitive rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Concept formation	6	194	Std. Mean Difference (IV, Random, 95% CI)	-0.04 [-0.32, 0.24]
1.1 Restorative versus compensative interventions	4	126	Std. Mean Difference (IV, Random, 95% CI)	-0.04 [-0.39, 0.31]
1.2 Restorative versus other interventions	2	68	Std. Mean Difference (IV, Random, 95% CI)	-0.03 [-0.52, 0.45]
2 Working memory	3	172	Std. Mean Difference (IV, Random, 95% CI)	-0.00 [-0.62, 0.61]
2.1 Restorative versus compensative interventions	1	68	Std. Mean Difference (IV, Random, 95% CI)	-0.02 [-0.50, 0.45]
2.2 Restorative versus other interventions	2	104	Std. Mean Difference (IV, Random, 95% CI)	-0.10 [-1.39, 1.18]
3 Activities of daily living	2	27	Std. Mean Difference (IV, Random, 95% CI)	-0.19 [-1.60, 1.22]
3.1 Restorative versus compensative interventions	2	27	Std. Mean Difference (IV, Random, 95% CI)	-0.19 [-1.60, 1.22]

Analysis 1.1. Comparison 1 Cognitive rehabilitation versus standard care, Outcome 1 Components of executive function.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 1 Cognitive rehabilitation versus standard care

Outcome: 1 Components of executive function

Analysis 1.2. Comparison 1 Cognitive rehabilitation versus standard care, Outcome 2 Activities of daily living.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 1 Cognitive rehabilitation versus standard care

Outcome: 2 Activities of daily living

Analysis 2.1. Comparison 2 Cognitive rehabilitation versus no treatment, Outcome 1 Components of executive function.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 2 Cognitive rehabilitation versus no treatment

Outcome: 1 Components of executive function

Analysis 2.2. Comparison 2 Cognitive rehabilitation versus no treatment, Outcome 2 Working memory.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 2 Cognitive rehabilitation versus no treatment

Outcome: 2 Working memory

Analysis 2.3. Comparison 2 Cognitive rehabilitation versus no treatment, Outcome 3 Activities of daily living.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 2 Cognitive rehabilitation versus no treatment

Outcome: 3 Activities of daily living

Analysis 3.1. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 1 Global executive function.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 1 Global executive function

Analysis 3.2. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 2 Components of executive function.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 2 Components of executive function

Analysis 3.3. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 3 Working memory.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 3 Working memory

Analysis 3.4. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 4 Activities of daily living.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 4 Activities of daily living

Analysis 3.5. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 5 Quality of life.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 5 Quality of life

Analysis 3.6. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 6 Vocational activities.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 6 Vocational activities

Analysis 3.7. Comparison 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation, Outcome 7 Vocational activities (dichotomous).

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 3 Experimental cognitive rehabilitation versus standard cognitive rehabilitation

Outcome: 7 Vocational activities (dichotomous)

Analysis 4.1. Comparison 4 Type of cognitive rehabilitation, Outcome 1 Concept formation.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 4 Type of cognitive rehabilitation

Outcome: 1 Concept formation

Analysis 4.2. Comparison 4 Type of cognitive rehabilitation, Outcome 2 Working memory.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 4 Type of cognitive rehabilitation

Outcome: 2 Working memory

Analysis 4.3. Comparison 4 Type of cognitive rehabilitation, Outcome 3 Activities of daily living.

Review: Cognitive rehabilitation for executive dysfunction in adults with stroke or other adult non-progressive acquired brain damage

Comparison: 4 Type of cognitive rehabilitation

Outcome: 3 Activities of daily living

ADDITIONAL TABLES

Table 1. Interventions and comparisons

Study	Country	Cognitive rehabilitation intervention	Classification of type of intervention	Comparison	Classification of type of comparison
Amos 2002	Australia	Salience	Compensative	No assistance	n/a
Carter 1980	USA	Cognitive remediation	Restorative	Standard care	n/a
Cheng 2006	Hong Kong	Awareness intervention	Restorative	Standard care	n/a
Chung 2007	UK	Video-feedback	Compensative	Verbal feedback	Restorative
Cicerone 2008	USA	Intensive neurorehabilitation	Compensative	Standard neurorehabilitation	Restorative
Dirette 1999	USA	Compensatory strategy training	Compensative	Computer activities	n/a
Fong 2009	Hong Kong	Problem-solving skills training	Restorative	Standard neurorehabilitation	Compensative

Table 1. Interventions and comparisons (Continued)

Goverover 2007	USA	Self awareness training	Restorative	Directive feedback	Compensative
Hewitt 2007	UK	Autobiographical memory cueing for problem solving	Restorative	General conversation	n/a
Hu 2003	China	Standard neurorehabilitation	Restorative	Standard care	n/a
Jorge 2010	USA	Problem-solving skills training	Restorative	No intervention	n/a
Levine 2000	Canada	Goal management training	Restorative	Standard care	n/a
Lundqvist 2010	Sweden	Computer working memory training	Restorative	No intervention	n/a
Man 2006	Hong Kong	Problem-solving skills training	Restorative	No intervention	n/a
O'Connor 2006	Canada	Goal management training	Restorative	Standard neurorehabilitation	Restorative
Rath 2003	USA	Group problem-solving training	Restorative	Standard neurorehabilitation	Restorative
Salazar 2000	USA	Hospital cognitive rehabilitation	Restorative	Home-based cognitive rehabilitation	Restorative
Spikman 2010	Netherlands	Problem-solving skills training	Restorative	Computer cognitive rehabilitation	Restorative
Westerberg 2007	Sweden	Computer working memory training	Restorative	No intervention	n/a

n/a: not applicable

Table 2. Outcome measurement tools and related outcomes

Outcome measure	Studies	Main executive function component	Protocol-related component
Behavioural Assessment of Dysexecutive Syndrome	Chung 2007 Spikman 2010	Global executive function	Global executive function

Table 2. Outcome measurement tools and related outcomes (Continued)

Category test of Halstead-Reitan Neuropsychological Test Battery	Man 2006	Abstract reasoning	Concept formation
Digit Span	Carter 1980 Westerberg 2007	Auditory working memory	Working memory (not on protocol)
Dysexecutive Questionnaire (DEX)	Spikman 2010	Executive problems in everyday life (self and proxy)	Global executive function
Executive Observation Scale	Spikman 2010	Therapist rated scale	Global executive function
Hayling and Brixton Test	Chung 2007	Inhibition and concept formation	Inhibition and concept formation
Lawton Instrumental ADL Index	Cheng 2006 Man 2006	Extended ADL	Extended ADL
Paced Auditory Serial Addition Test (PASAT)	Dirette 1999 Lundqvist 2010 Salazar 2000 Westerberg 2007	Auditory working memory	Working memory (not on protocol)
Problem Solving Inventory	Rath 2003	Self appraisal of problem-solving behaviours	Concept formation
Problem Solving Questionnaire	Man 2006 Rath 2003	Self monitoring and logical thinking	Concept formation
Problem Solving Role Playing Test	Rath 2003	Face-to-face interpersonal problem solving	Concept formation
Proof reading	Levine 2000	Holding goals in mind, monitoring	Planning
Quality of Life after Brain Injury (QOLIBRI)	Spikman 2010	Quality of life	Quality of life
Raven's Progressive Matrices	Fong 2009 Westerberg 2007	Non-verbal reasoning	Concept formation
Role Resumption List	Spikman 2010	Changes in amount and quality of activities	Participation in vocational activities
Span-Board	Westerberg 2007	Visuo-spatial working memory	Working memory (not on protocol)

Table 2. Outcome measurement tools and related outcomes (Continued)

Stroop Test	Jorge 2010 Spikman 2010 Westerberg 2007	Cognitive flexibility	Flexibility
Tower of London Test	Spikman 2010	Strategy formation	Planning
Trail Making Test	Cicerone 2008 Jorge 2010 Spikman 2010	Visual working memory	Working memory (not on protocol)
Treatment Goal Attainment	Spikman 2010	The extent of goal achievement	Planning
Wisconsin Card Sorting Test	Amos 2002 Rath 2003 Salazar 2000	Perseveration	Concept formation
Assessment of Awareness of Disability	Goverover 2007	Discrepancy between task awareness and performance	Concept formation
Assessment of Motor and Process Skills	Goverover 2007	Motor and process skills of ADL	ADL
Booklet Category Test	Cicerone 2008	Abstract reasoning - concept formation	Concept formation
Category Test of the Halstead Reitan Neuropsychological Test Battery	Man 2006	Postulate hypothesis regarding similarities and differences	Concept formation
Community Integration Questionnaire	Goverover 2007	Home and social integration and productive activities	Participation in vocational activities
Everyday Descriptions Task	Hewitt 2007	Planning	Planning
Functional Independence Measure	Cheng 2006	Independence with ADL	ADL
Grouping	Levine 2000	Holding goals in mind, subgoal analysis, monitoring	Working memory
Key Search Test	Fong 2009	Problem solving (planning, strategy formation, monitoring metacognition)	Planning
Means-Ends Problem Solving Measure	Fong 2009	Interpersonal problem solving	Concept formation
Metacomponential Interview	Fong 2009	Reasoning-concept formation	Concept formation

Table 2. Outcome measurement tools and related outcomes (Continued)

Cognistat	Hu 2003	Similarities and judgement sections	Concept formation
Perceived Quality of Life Scale	Cicerone 2008	Quality of life	Quality of life
Problem Solving Questionnaire	Man 2006	Identifying solutions to problems	Concept formation
Room Layout	Levine 2000	Subgoal analysis, monitoring	Working memory
Self Awareness of Deficits Interview	Cheng 2006	Self awareness of deficits, implications and goals	Concept formation
Self-Regulation Skills Interview	Goverover 2007	Self monitoring, problem recognition and anticipation	Concept formation
Six Elements Test	Fong 2009	Problem solving (planning, strategy formation, monitoring metacognition)	Planning
Social Problem-Solving Video Measure	Fong 2009	Real-life problem solving	Concept formation
Test of Planning	O'Connor 2006	Planning	Planning
Vocational Integration Scale	Cicerone 2008	Vocational and educational outcomes	Participation in vocational activities

ADL: activities of daily living

Cognistat: Neurobehavioural Cognitive Status Examination

DEX: Dysexecutive Questionnaire

PASAT: Paced Auditory Serial Addition Test

QOLIBRI: Quality of Life after Brain Injury

Table 3. Outcome measure selection rationale

Study	Outcome measures	Selected for review	Rationale
Amos 2002	Wisconsin Card Sorting Test	Wisconsin Card Sorting Test	The only executive function measure
Carter 1980	Digit Span Test	Digit Span Test	The only measure related to working memory and hence, executive function
Cheng 2006	Self Awareness of Deficits Interview Functional Independence Measure	Self Awareness of Deficits Interview Functional Independence Measure	The only measure of self awareness The FIM measures basic ADL,

Table 3. Outcome measure selection rationale (Continued)

	Lawton Instrumental Activities of Daily Living Scale	Lawton Instrumental Activities of Daily Living Scale	and the Lawton measures advanced ADL
Chung 2007	BADS Hayling and Brixton Tests Adapted Nottingham Stroke Dressing Assessment	BADS Hayling and Brixton Tests Adapted Nottingham Stroke Dressing Assessment	BADS is a global executive function measure whereas the Hayling test measures inhibition while the Brixton Test measures concept formation The Adapted Nottingham Stroke Dressing Assessment was the only ADL assessment used
Cicerone 2008	Trail Making Test B COWAT Booklet Category Test Perceived Quality of Life Scale Community Integration Questionnaire	Trail Making Test B Booklet Category Test Perceived Quality of Life Scale Community Integration Questionnaire	Working memory measure Concept formation test preferred to the COWAT due to the latter's weighting on semantic memory strategies and less about actual concept formation Quality of life measure Vocational components included
Dirette 1999	PASAT	PASAT	The only working memory measure
Fong 2009	Six Elements Test for problem solving Key Search Tests for everyday problem solving SPSVM MEPSM Raven's Progressive Matrices Metacomponential Interview	Raven's Progressive Matrices Key Search	This has established reliability and validity for concept formation. The SPSVM, MEPSM and Metacomponential Interview all relate to concept formation but the author of the SPSVM stated that it requires further reliability studies for people with brain injury, the MEPSM was validated for psychiatric patients and the Metacomponential Interview scoring is based partly on interviewer prompts and no reliability figures are given. Thus, Raven's Progressive Matrices appears to be the most valid and reliable outcome measure for concept formation. The Six Elements and Key Search are both planning measure. As the Six Elements relates to competing tasks, the Key Search outcome possibly has a more concrete end point of

Table 3. Outcome measure selection rationale (Continued)

			finding the key than the Six Elements, which is about the completion of part tasks
Goverover 2007	AAD SRSI	AAD	Both measures are related to concept formation but the AAD measure discrepancy between self rating and observed function rating whereas the SRSI is based on self evaluation. The AAD appears to be a stronger option as it seems to be more valid for picking up instances of reduced self awareness
Hewitt 2007	Everyday Descriptions Task	Everyday Descriptions Task	The only post measure used. The effectiveness component of the outcome measure was used as number of steps could potentially be a positive or negative factor
Hu 2003	Cognistat	Cognistat	Executive function components of the only measure used. These are similarities and judgement, which are reasoning components, and will be under concept formation for this review
Jorge 2010	Stroop Test Trail Making Test	Stroop Test Trail Making Test	The only measures used for cognitive flexibility and working memory respectively
Levine 2000	Grouping Room Layout Proof Reading	Room Layout Proof Reading	Both Grouping and Room Layout measure working memory, but the Room Layout Task has a stronger relationship to a real-life task, whereas, grouping is closer to an alternating attention task Proof reading was the only measure of planning
Lundqvist 2010	PASAT	PASAT	The only working memory measure
Man 2006	Problem Solving Questionnaire Category Test of the Halstead-Reitan Neuropsychological Test Battery	Category Test of the Halstead-Reitan Neuropsychological Test Battery	Author's state that it is supported by extensive research compared with the Problem Solving Questionnaire that had just been validated for the study
O'Connor 2006	Test of Planning	Test of Planning	The only planning test

Table 3. Outcome measure selection rationale (Continued)

Rath 2003	Wisconsin Card Sorting Test Problem Solving Inventory Problem Solving Questionnaire Problem Solving Role Playing Test	Wisconsin Card Sorting Test	All the measures appear to have undergone validation processes but the Wisconsin Card Sorting Test was chosen due to its widespread use and advantage to this meta-analysis
Salazar 2000	PASAT Wisconsin Card Sorting Test	PASAT Wisconsin Card Sorting Test	The only measures for working memory and concept formation respectively
Spikman 2010	BADS Trail Making Stroop Tower of London Treatment Goal Attainment DEX EOS	BADS Trail Making Stroop Test Tower of London Test	The selected measures are established tests whereas Treatment Goal Attainment was developed for the study and the DEX and EOS and self rating and observational rating scales that do not involve participant performance of actual tasks
von Cramon 1991	Tower of Hanoi	Towers of Hanoi	The only planning measure
Westerberg 2007	PASAT Digit Span Span board Stroop Test Raven's Progressive Matrices	PASAT Stroop Test Raven's Progressive Matrices	The first 3 measures are for working memory and the analysis has not subdivided working therefore, the widest and most established was chosen The Stroop Test and Raven's Progressive Matrices were the only measures of flexibility and concept formation

AAD: Assessment of Awareness of Disability

ADL: activities of daily living

BADS: Behavioural Assessment of Dysexecutive Syndrome

Cognistat: Neurobehavioural Cognitive Status Examination

COWAT: Controlled Oral Word Association Test

DEX: Dysexecutive Questionnaire

EOS: Executive Observation Scale

FIM: Functional Independence MeasureMEPSM: Means-Ends Problem Solving Measure

PASAT: Paced Auditory Serial Addition Test

SPSVM: Social Problem-Solving Video Measure

SRSI: Self Regulation Skills Interview

APPENDICES

Appendix I. MEDLINE search strategy

We used the following search strategy for MEDLINE (Ovid) and adapted it for the other databases.

Ovid (1950 to present)

1. cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or cerebrovascular trauma/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2. (stroke\$ or poststroke\$ or post-stroke\$ or cva\$).tw.
3. ((cerebrovascular or cerebral vascular) adj3 (accident? or insult?)).tw.
4. ((cerebral or brain\$ or vertebrobasilar) adj5 (infarct\$ or isch?emi\$ or thrombo\$ or apoplexy or emboli\$)).tw.
5. ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed)).tw.
6. ((trauma\$ or acquired) adj5 brain injur\$).tw.
7. brain injuries/ or exp brain concussion/ or exp brain hemorrhage, traumatic/ or brain injury, chronic/
8. Brain Damage, Chronic/
9. craniocerebral trauma/ or head injuries, closed/ or exp intracranial hemorrhage, traumatic/
10. exp encephalitis/ or exp meningitis, viral/
11. (encephalitis or meningitis).tw.
12. brain abscess/ or exp central nervous system infections/
13. (brain abscess or brain infection\$ or cerebral infection\$).tw.
14. or/1-13
15. cognition disorders/ or exp memory disorders/ or motor skills disorders/ or perceptual disorders/
16. (executive dysfunction or dysexecutive syndrome or dysexecutive function).tw.
17. ((executive function\$ or cognit\$ or attention or memory or initiation or initiating or awareness) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
18. ((self-awareness or self-monitoring or self-inhibiting or self-evaluation) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
19. ((goal management or goal selection or goal setting or goal-directed behaviour or goal-directed activit\$) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
20. ((strategy formation or planning or organisation or organization or time management or problem solving or decision making or sequencing or sequence of steps) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
21. ((functional activities or functional task\$ or execut\$ task\$ or leisure) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
22. ((activit\$ of daily living or ADL or PADL or DADL or IADL or washing or grooming or shaving or cleaning teeth or brushing teeth or cleaning dentures or bathing or dressing or applying makeup or toileting or personal care or personal hygiene or cooking or hot drink\$ or meal or meals or kitchen activit\$ or kitchen task\$ or household activit\$ or household task\$ or domestic activit\$ or domestic task\$ or vacuuming or ironing or laundry or taking medic\$ or job or employment or driving) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
23. ((visual processing or auditory processing or gait or transfer) adj5 (disorder\$ or dysfunction or impaired or impairment or difficult\$ or problem\$ or deficit\$ or disturbance\$ or disabilit\$)).tw.
24. or/15-23
25. ((activit\$ of daily living or ADL or PADL or DADL or IADL or washing or grooming or shaving or cleaning teeth or brushing teeth or cleaning dentures or bathing or dressing or applying makeup or toileting or personal care or personal hygiene or cooking or hot drink\$ or meal or meals or kitchen activit\$ or kitchen task\$ or household activit\$ or household task\$ or domestic activit\$ or domestic task\$ or vacuuming or ironing or laundry or taking medic\$ or job or employment or driving) adj5 practice).tw.
26. "Biofeedback (Psychology)"/ or feedback, psychological/
27. (biofeedback or feedback or video-feedback).tw.
28. ((activit\$ of daily living or ADL or PADL or DADL or IADL or washing or grooming or shaving or cleaning teeth or brushing teeth or cleaning dentures or bathing or dressing or applying makeup or toileting or personal care or personal hygiene or cooking or hot drink\$ or meal or meals or kitchen activit\$ or kitchen task\$ or household activit\$ or household task\$ or domestic activit\$ or

domestic task\$ or vacuuming or ironing or laundry or taking medic\$ or job or employment or driving) adj5 (training or therapy or rehabilitation)).tw.

29. "Activities of Daily Living"/

30. Cognitive Therapy/ or behavior therapy/

31. ((executive function\$ or cognitive or behavior or behaviour or gait or transfer or goal or goals or problem solving or functional ability or functional activity or planning or organisation or organization or mirror or attention or memory) adj5 (training or therapy or rehabilitation)).tw.

32. (internal strateg\$ or external strateg\$ or time pressure management or self-monitoring or response cost or stimulus control or vanishing cues or self-instruction or pictorial instruction or environmental modification or errorless learning).tw.

33. "Task Performance and Analysis"/

34. or/25-33

35. 34 and 24 and 14

CONTRIBUTIONS OF AUTHORS

The views expressed here are those of the authors and not necessarily those of the Chief Scientist Office or the Scottish Government who fund two of the authors.

Charlie Chung led the review. He ran the searches, excluded obviously irrelevant references, applied inclusion criteria, extracted methodological details, extracted trial details and data, carried out data analysis and wrote all drafts of the review. Tanya Campbell acted as a second review author and provided content expertise relating to the intervention. Alex Pollock provided methodological expertise. Tanya Campbell and Alex Pollock applied inclusion criteria, extracted methodological details, extracted trial details and data, and read and commented on drafts of the review. Brian Durward acted as an additional review author; he read and commented on drafts of the review and assisted with data extraction. Suzanne Hagen provided additional statistical expertise and read and commented on drafts of the review.

DECLARATIONS OF INTEREST

One author has been involved in a study that is included in this review. Charlie Chung completed an MSc dissertation entitled "The effectiveness of video-feedback in acute stroke rehabilitation: a pilot study" in 2007. This was a pilot RCT of video-feedback intervention on executive function that was not powered to show a difference between the trial groups. A poster abstract was included in the UK Stroke Forum 2007 Conference abstract book, but the study is otherwise unpublished.

Four authors are involved in other ongoing work relating to the subject of this review. This Cochrane review forms part of the first author's PhD studies. A qualitative study to explore how participants with stroke and healthy volunteers express executive function processes through narrative and observed behaviour will also be carried out as part of his PhD studies. Three other authors, Alex Pollock, Tanya Campbell and Brian Durward, are involved in the supervision of this PhD.

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

The working memory category was not included in the published review protocol. Working memory is a system that co-ordinates the perceptual information entering our brains, with procedural and longer-term memories to inform planning processes. The executive function system co-ordinates the information and has limited capacity, and, thus, we considered that including working memory as a secondary outcome in this review, would add value by increasing our knowledge of the impact of the intervention on a more complex system in comparison to the specific executive function components.

We included goal management training as an example of a compensative intervention in the protocol but during the course of our intervention categorisation, we changed this to being a restorative intervention on the basis that the process of goal management may be considered to be a process that individuals commonly use for solving problems, and not an alternative method.

INDEX TERMS

Medical Subject Headings (MeSH)

*Executive Function; *Stroke Rehabilitation; Activities of Daily Living; Brain Damage, Chronic [*rehabilitation]; Cognition Disorders [*rehabilitation]; Randomized Controlled Trials as Topic

MeSH check words

Adult; Humans