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Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury (Review).

Linden, M., Hawley, C., Blackwood, B., Evans, J., Anderson, V., & O'Rourke, C. (2016). Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury (Review). *Cochrane Database of Systematic Reviews*, 2016(7), Article CD011020. <https://doi.org/10.1002/14651858.CD011020.pub2>

Published in:
Cochrane Database of Systematic Reviews

Document Version:
Publisher's PDF, also known as Version of record

Queen's University Belfast - Research Portal:
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Cochrane Database of Systematic Reviews 2016, Issue 7. Art. No.: CD011020.

DOI: 10.1002/14651858.CD011020.pub2.

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TABLE OF CONTENTS

| | |
|--|----|
| HEADER | 1 |
| ABSTRACT | 1 |
| PLAIN LANGUAGE SUMMARY | 3 |
| SUMMARY OF FINDINGS FOR THE MAIN COMPARISON | 5 |
| BACKGROUND | 8 |
| OBJECTIVES | 9 |
| METHODS | 9 |
| RESULTS | 13 |
| Figure 1. | 14 |
| Figure 2. | 16 |
| Figure 3. | 18 |
| Figure 4. | 20 |
| DISCUSSION | 20 |
| AUTHORS' CONCLUSIONS | 22 |
| ACKNOWLEDGEMENTS | 22 |
| REFERENCES | 23 |
| CHARACTERISTICS OF STUDIES | 27 |
| DATA AND ANALYSES | 39 |
| Analysis 1.1. Comparison 1 Technological aid vs internet resource comparison, Outcome 1 Executive functioning (various measures). | 39 |
| Analysis 1.2. Comparison 1 Technological aid vs internet resource comparison, Outcome 2 CBCL Internalising subscale. | 40 |
| Analysis 2.1. Comparison 2 Technological aid vs internet resource comparison: Subgroups, Outcome 1 Executive functioning BRIEF/GEC (moderate). | 41 |
| Analysis 2.2. Comparison 2 Technological aid vs internet resource comparison: Subgroups, Outcome 2 Executive functioning BRIEF/GEC (severe). | 41 |
| APPENDICES | 41 |
| CONTRIBUTIONS OF AUTHORS | 51 |
| DECLARATIONS OF INTEREST | 51 |
| SOURCES OF SUPPORT | 51 |
| DIFFERENCES BETWEEN PROTOCOL AND REVIEW | 51 |

[Intervention Review]

Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury

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Editorial group: Cochrane Injuries Group.

Publication status and date: New, published in Issue 7, 2016.

Review content assessed as up-to-date: 30 September 2015.

Citation: Linden M, Hawley C, Blackwood B, Evans J, Anderson V, O'Rourke C. Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury. *Cochrane Database of Systematic Reviews* 2016, Issue 7. Art. No.: CD011020. DOI: 10.1002/14651858.CD011020.pub2.

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ABSTRACT

Background

The use of technology in healthcare settings is on the increase and may represent a cost-effective means of delivering rehabilitation. Reductions in treatment time, and delivery in the home, are also thought to be benefits of this approach. Children and adolescents with brain injury often experience deficits in memory and executive functioning that can negatively affect their school work, social lives, and future occupations. Effective interventions that can be delivered at home, without the need for high-cost clinical involvement, could provide a means to address a current lack of provision.

We have systematically reviewed studies examining the effects of technology-based interventions for the rehabilitation of deficits in memory and executive functioning in children and adolescents with acquired brain injury.

Objectives

To assess the effects of technology-based interventions compared to placebo intervention, no treatment, or other types of intervention, on the executive functioning and memory of children and adolescents with acquired brain injury.

Search methods

We ran the search on the 30 September 2015. We searched the Cochrane Injuries Group Specialised Register, the Cochrane Central Register of Controlled Trials (CENTRAL), Ovid MEDLINE(R), Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid OLDMEDLINE(R), EMBASE Classic + EMBASE (OvidSP), ISI Web of Science (SCI-EXPANDED, SSCI, CPCI-S, and CPSI-SSH), CINAHL Plus (EBSCO), two other databases, and clinical trials registers. We also searched the internet, screened reference lists, and contacted authors of included studies.

Selection criteria

Randomised controlled trials comparing the use of a technological aid for the rehabilitation of children and adolescents with memory or executive-functioning deficits with placebo, no treatment, or another intervention.

Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury (Review)

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Data collection and analysis

Two review authors independently reviewed titles and abstracts identified by the search strategy. Following retrieval of full-text manuscripts, two review authors independently performed data extraction and assessed the risk of bias.

Main results

Four studies (involving 206 participants) met the inclusion criteria for this review.

Three studies, involving 194 participants, assessed the effects of online interventions to target executive functioning (that is monitoring and changing behaviour, problem solving, planning, etc.). These studies, which were all conducted by the same research team, compared online interventions against a 'placebo' (participants were given internet resources on brain injury). The interventions were delivered in the family home with additional support or training, or both, from a psychologist or doctoral student. The fourth study investigated the use of a computer program to target memory in addition to components of executive functioning (that is attention, organisation, and problem solving). No information on the study setting was provided, however a speech-language pathologist, teacher, or occupational therapist accompanied participants.

Two studies assessed adolescents and young adults with mild to severe traumatic brain injury (TBI), while the remaining two studies assessed children and adolescents with moderate to severe TBI.

Risk of bias

We assessed the risk of selection bias as low for three studies and unclear for one study. Allocation bias was high in two studies, unclear in one study, and low in one study. Only one study (n = 120) was able to conceal allocation from participants, therefore overall selection bias was assessed as high.

One study took steps to conceal assessors from allocation (low risk of detection bias), while the other three did not do so (high risk of detection bias).

Primary outcome 1: Executive functioning: Technology-based intervention versus placebo

Results from meta-analysis of three studies (n = 194) comparing online interventions with a placebo for children and adolescents with TBI, favoured the intervention immediately post-treatment (standardised mean difference (SMD) -0.37, 95% confidence interval (CI) -0.66 to -0.09; P = 0.62; I² = 0%). (As there is no 'gold standard' measure in the field, we have not translated the SMD back to any particular scale.) This result is thought to represent only a small to medium effect size (using Cohen's rule of thumb, where 0.2 is a small effect, 0.5 a medium one, and 0.8 or above is a large effect); this is unlikely to have a clinically important effect on the participant.

The fourth study (n = 12) reported differences between the intervention and control groups on problem solving (an important component of executive functioning). No means or standard deviations were presented for this outcome, therefore an effect size could not be calculated.

The quality of evidence for this outcome according to GRADE was very low. This means future research is highly likely to change the estimate of effect.

Primary outcome 2: Memory

One small study (n = 12) reported a statistically significant difference in improvement in sentence recall between the intervention and control group following an eight-week remediation programme. No means or standard deviations were presented for this outcome, therefore an effect size could not be calculated.

Secondary outcomes

Two studies (n = 158) reported on anxiety/depression as measured by the Child Behavior Checklist (CBCL) and were included in a meta-analysis. We found no evidence of an effect with the intervention (mean difference -5.59, 95% CI -11.46 to 0.28; I² = 53%). The GRADE quality of evidence for this outcome was very low, meaning future research is likely to change the estimate of effect.

A single study sought to record adverse events and reported none. Two studies reported on use of the intervention (range 0 to 13 and 1 to 24 sessions). One study reported on social functioning/social competence and found no effect. The included studies reported no data for other secondary outcomes (that is quality of life and academic achievement).

Authors' conclusions

This review provides low-quality evidence for the use of technology-based interventions in the rehabilitation of executive functions and memory for children and adolescents with TBI. As all of the included studies contained relatively small numbers of participants (12 to 120), our findings should be interpreted with caution. The involvement of a clinician or therapist, rather than use of the technology, may have led to the success of these interventions. Future research should seek to replicate these findings with larger samples, in other regions, using ecologically valid outcome measures, and reduced clinician involvement.

PLAIN LANGUAGE SUMMARY

Using technology to rehabilitate children and adolescents with acquired brain injury

Review question

We aimed to assess the effects of technology-based interventions in rehabilitating children and adolescents with acquired brain injury.

Background

Acquired brain injury is defined as any injury to the brain that occurs following birth and is the result of illness, medical conditions, or trauma. After acquired brain injury a person can experience difficulties with executive functions and memory. Executive functions are brain processes that involve planning and emotional control, which govern the ability to start and stop our actions. Memory processes allow us to store and recall information about our world. Executive functions also include an aspect of memory called working memory. Technology is increasingly being used to help children and adolescents recover from acquired brain injury. Technological aids used to rehabilitate memory and executive functions include pagers, smartphones, internet-based interventions, and voice recorders.

Search date

We performed the searches in September 2015.

Study characteristics

We identified four studies (including 206 participants) that investigated the effectiveness of technology-based interventions to rehabilitate children and adolescents with traumatic brain injury. All four studies were conducted in North America, with three originating from the same research team.

One study with 120 participants used an online Counselor-Assisted Problem Solving (CAPS) intervention to rehabilitate executive functioning in adolescents aged 12 to 17 years.

One study with 35 participants used a Teen Online Problem-Solving intervention to target the executive functioning of adolescents aged 11 to 18 years.

One study with 40 participants used an online Family Problem Solving intervention to target outcomes such as behaviour and aspects of executive functioning in children aged 5 to 16 years.

One study with 12 participants used a computer program to target cognitive-communication skills including memory and aspects of executive functions in adolescents and young adults aged 12 to 21 years.

Study funding sources

All funding sources were in the USA or Canada. One study was funded by the Colorado Department of Human Services and two National Institutes of Health (NIH) awards. A second study was also funded by a NIH grant. One study was funded by a hospital charity in addition to the Easter Seal Research Institute and Apple Canada. The final study was supported by the Ohio Department of Safety.

Key results

This review found evidence that interventions employing technological aids did improve executive functions in adolescents with traumatic brain injury (i.e. a brain injury resulting from a road traffic accident, fall, or blow to the head). However, this result was relatively modest and is unlikely to have a clinically important effect on the child. One study employed technology to improve memory in adolescents with TBI and showed an improvement for the intervention group. It was not possible to determine how effective this

approach was as the study failed to include adequate statistical information. Two studies examined the secondary outcomes of anxiety and depression but did not show any effect between the intervention and control groups at 6 months follow-up. Only one study recorded adverse events, and reported that none occurred. Two studies reported on the amount of use the intervention received. One study reported improvements in social functioning/social competence for the intervention group. No data were reported which related to the review's other secondary outcomes.

Quality of the evidence

We found the quality of evidence for all outcomes to be low, which means future research is likely to change the estimate of effect. All four studies were small, and it was not always possible to conceal group allocation to participants. Three studies failed to conceal group allocation to those who measured the outcomes.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON *[Explanation]*

| Technological aid compared to internet resource for children or adolescents with acquired brain injury | | | | | | |
|---|--|---|--------------------------|------------------------------|--|--|
| Patient or population: Children or adolescents with acquired brain injury Settings: Home Intervention: Technological aid ¹ Comparison: Internet resource ² | | | | | | |
| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of Participants (studies) | Quality of the evidence (GRADE) | Comments |
| | Assumed risk | Corresponding risk | | | | |
| | Internet resource | Technological aids | | | | |
| Executive functioning (various measures) GEC on the BRIEF (2 studies); HCSBS (1 study) | - | The mean executive functioning (various measures) in the intervention groups was 0.37 standard deviations lower (0.66 to 0.09 lower) | - | 194 (3 studies) | ⊕⊕⊕○ very low ^{3,4,5} | SMD -0.37 (-0.66 to -0.09) |
| Memory Recalling Sentences subtest | See comment | See comment | - | 12 (1 study) | See comment | The results show a statistically significant difference between the intervention and control groups in regards to memory (P = 0.03) ⁶ |
| Quality of life - not reported | See comment | See comment | Not estimable | - | See comment | No study measured this outcome |

| | | | | | | |
|---|-------------|---|---------------|--------------------|--|---|
| Psychological functioning (mood, etc.) CBCL internalising scale (Parent/primary caregiver rates each item on a 3-step response scale: (0) not true, (1) somewhat or sometimes true, and (2) very true or often true. The item responses are scored using a program that accompanies the instrument, providing both raw total scores and T scores, normed by gender, for each domain) | - | The mean psychological functioning (mood, etc.) in the intervention groups was 5.59 lower (11.46 lower to 0.28 higher) | - | 158 (2 studies) | ⊕⊕⊕○ very low ^{6,10,11} | Composites were imported as T scores with a mean of 50 and an SD of 10, with higher scores indicating more problems |
| Social functioning - not reported | See comment | See comment | Not estimable | - | See comment | No study measured this outcome |
| Academic achievement - not reported | See comment | See comment | Not estimable | - | See comment | No study measured this outcome |
| Adverse events | See comment | See comment | Not estimable | - | See comment | One study (120 participants) reported on adverse events as an outcome. None were identified |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

BRIEF: Behavior Rating Inventory of Executive Function; **CBCL:** Child Behavior Checklist; **CI:** confidence interval; **GEC:** Global Executive Composite; **HCSBS:** Home and Community Social Behavior Scales; **SD:** standard deviation; **SMD:** standardised mean difference

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹Technological aids may be compensatory or restorative in function. The former seek to reduce the load on compromised cognitive processes (for example web-based scheduling or voice recorders for memory deficits), while the latter attempt to retrain lost skills to repair these processes or reduce impairment.

²'Internet resource' means that the comparator group were given URLs providing educational information about acquired brain injury.

³Two studies ([Wade 2010](#); [Kurowski 2013](#)), used the psychometrically validated Behavior Rating Inventory of Executive Function (BRIEF) ([Gioia 2000](#)), and one study ([Wade 2006](#)), used a subscale of the Home and Community Social Behavior Scales (HCSBS) to assess executive functioning ([Merrell 2001](#)). For the former (the Global Executive Composite of the BRIEF), a high number is suggestive of greater pathology; for the latter (the HCSBS), a low number indicates greater pathology.

⁴Blinding is impossible for participants or personnel; blinding of outcome assessors was not performed in two studies.

⁵None of the included trials used an ecologically valid measure of executive functioning, instead utilising paper-and-pencil tests which, while psychometrically valid, are arguably a less effective way of measuring executive functions.

⁶All studies are small, with a total sample size less than 200.

⁷Blinding is impossible for participants or personnel; blinding of outcome assessors not reported.

⁸Study is extremely small (n = 12). Too few people included in the analyses to provide reliable results (P values from small samples are statistically unreliable (due to Type 1 and 2 error)). In addition, measures of central tendency and dispersion were not provided for these findings.

⁹Analysis of covariances were chosen to compare groups across time, whilst controlling for group differences at baseline. Only data from the Recalling Sentences subtest (assessing memory) and The Adolescent Word Test - task A-brand names (assessing problem solving/reasoning) together with various language measures were reported. The results show a statistically significant difference between the intervention and control groups in regards to memory (P = 0.03).

¹⁰Blinding is impossible for participants or personnel.

¹¹¹² of 53%.

BACKGROUND

Medical advances have resulted in increasing numbers of children surviving a brain injury. Acquired brain injury (ABI) is a broad term that includes injuries related to illness or medical conditions (for example meningitis, stroke, brain tumours, hypoxia) in addition to those caused by trauma (for example road traffic crashes, falls, assaults). ABI is defined as any injury to the brain occurring after birth (Teasdale 2007). While the aetiology of the injury may vary, outcomes for children are dependent on a variety of factors such as severity of injury (Barker-Collo 2007), injury site (Bates 2001), pre-injury status (McKinlay 2010), age (Corkin 1989), socioeconomic status (Yeates 2004), and family (Taylor 2001). Whilst data are available on the prevalence of traumatic brain injury (TBI) (Hawley 2003; McKinlay 2008; Parslow 2005; Rushworth 2008), no such reliable figures exist for the broader population of children with ABI. However, both groups face a similar range of deficits that can severely limit their ability to fully participate in their lives and that reduce overall quality of life.

Description of the condition

Following brain injury, the child is at increased risk of functional difficulties in areas such as attention, memory, planning, affect, and co-ordination. A large proportion of children will also experience fatigue, which affects their ability to focus on, and carry out, tasks (Hooper 2004). This also has the effect of reducing the amount of cognitive resources available for processes such as information processing, attention, and memory. Tasks that may once have been accomplished with ease now require increased levels of mental effort, which in turn leads to fatigue and results in the child feeling frustrated.

These deficits can lead to children falling behind in their school work (Ewing-Cobbs 2004; Hawley 2004), having reduced social participation (Anderson 2013; Bedell 2004), and experiencing social difficulties (for example bullying) (Backhouse 1999; Boylan 2009). Research suggests that children who have poor peer interactions are at increased risk of dropping out of education and engaging in criminality (Parker 1993). The lack of a supportive peer network may thus result in childhood survivors of brain injury missing out on education, which has clear implications for their future career prospects. Children and young people who experience difficulties with impulsivity and control following injury may also be more likely to engage in behaviours that bring them into contact with the criminal justice system. A recent study has demonstrated a high prevalence (65% of 186 participants) of young male offenders who self reported at least one incidence of TBI, with multiple injuries associated with increasingly violent crimes (Williams 2010).

There are no consistent indices of severity across the spectrum of ABI, however for TBI severity measures are well established. Such injury is initially classified as being either mild, moderate,

or severe, and can be described in terms of the duration of post-traumatic amnesia (PTA) (Marosszeky 1997), loss of consciousness (LOC) (WHO 2008), or the widely used Glasgow Coma Scale (GCS) (Teasdale 1974). Children with PTA of less than one hour or LOC of less than 30 minutes are described as having a mild injury. Those between 1 and 24 hours PTA, or less than 6 hours LOC, are classified as moderate, while those 1 to 7 days PTA, and more than 6 hours LOC, are described as severe. Higher scores on the GCS indicate less severe injury (13 to 15 = Mild, 9 to 12 = Moderate, 3 to 8 = Severe). However, only the severe injury category has consistently been shown to have predictive power in relation to severity and persistence of short- and long-term outcomes (Klonoff 1993).

Rehabilitation of cognitive functioning is traditionally undertaken by a team of healthcare professionals. Clinical psychologists, speech and language therapists, occupational therapists, and psychiatrists may work with the patient. A variety of interventions may be applied by these professionals depending on the individual deficits of the child. Approaches such as the cognitive remediation programme (CRP), in Butler 2002, or the 'Pay Attention' technique, in Thomson 2001, may be used to address deficits in attention or to teach behavioural regulation, which among other processes (e.g. planning, attention and inhibition), are associated with executive functioning. Compensatory approaches for memory deficits have included pencil-and-paper diaries (Ho 2011), calendars, wall charts, and notebooks (Evans 2003).

Description of the intervention

Technological aids, used in the rehabilitation of child and adolescent survivors of brain injury, come in a variety of forms, including electronic organisers, pagers, mobile phones, web-based scheduling, and voice recorders. For example, the NeuroPage system utilised a paging service that sent a reminder or cue to an individual at predetermined points (Wilson 1997). This system removed the need for the individual to remember to use the device, did not require complicated instructions on its use, and was relatively discrete (Wilson 1997). Recently, the use of smartphones has introduced the possibility of creating applications (or 'apps') that can target specific cognitive deficits, whilst being discreetly contained within an attractive and desirable piece of technology (Russell 2011; Svoboda 2009). This is an important consideration for adolescents, who may fear social ridicule if asked to use a conspicuous device that may draw attention to their deficits. An example is the 'It's Done' app (It's Done! 2012), which enables individuals to 'check-off' tasks as they are accomplished, and review these to ensure they have been achieved. This app can also send a text message or email to a significant other to inform them that the individual has completed the specified task (for example take medication). The above approaches have been tested in adult populations (Svoboda 2009; Wilson 1997), who are better equipped

to regain functioning, rather than learn a completely new task, as in the case of children or adolescents.

The distinction between strategies intended to restore cognitive functioning and those intended to compensate for a deficit are unclear, as both utilise learning and repetition (Sohlberg 2001). However, external aids used in a compensatory fashion are generally viewed as a means to reduce the cognitive load and enable the successful completion of a task. Those intended to restore functioning rely on the restructuring of neural pathways which are dependent on the site and extent of injury.

How the intervention might work

Many technological aids are viewed as a method to compensate for, rather than restore, reduced memory or executive functions. They act as a means to reduce the load on compromised processes in order to allow a person to successfully conduct a task. It has been suggested that compensatory strategies should be purposeful and goal-directed, used to compensate for a particular breakdown; should rely on pre-existing behaviours that are adapted to compensate for a deficit; should be employed flexibly to fit a given situation; are unique to the individual; and are spontaneous rather than trained (Simmons-Mackie 1997). Clinicians should attempt to build upon existing strategies, tailor these to the individual's needs, and provide systematic direct training (Sohlberg 2001).

Restorative approaches to cognitive rehabilitation often focus on hierarchically organised retraining exercises that target specific functions such as memory or executive functioning (Ylvisaker 2002). The aim of such approaches is to repair cognitive processes or reduce impairment. Technology can be used alongside clinician-modified tasks to promote restoration of functions through successful performance and repetition (Ylvisaker 2002).

Two possible systems may be employed in teaching the use of a technological aid, the non-declarative learning system and prospective memory (Sohlberg 2001). For many survivors of brain injury, functionality of the declarative system is impaired, and learning is supported by the non-declarative system, which requires greater time and effort. The declarative learning system represents the knowledge we possess, and includes the conscious information about our lives. It is said to be divided into semantic (that is facts and meaning) and episodic (that is autobiographical events) memory systems (Tulving 1972). Damage to episodic memory may leave semantic systems intact but reduce functionality and compromise declarative learning (Tulving 1983). The non-declarative learning system, which allows us to learn systems and procedures without conscious awareness, is often preserved following brain injury (Sohlberg 2001). This system functions by the gradual acquisition of learning over time (Poldrack 2001), and may therefore be used by clinicians to train childhood survivors of brain injury to use external aids.

Prospective memory processes allow us to plan future behaviours and act on these at the appropriate time (Baddeley 2007). In order

to accomplish such a task the individual must plan the behaviour, keep the steps required to accomplish this in mind, recall the task, and take action (Sohlberg 2001). Prospective memory processing is said to consist of five components: knowledge, planning, monitoring, content recall, and output monitoring (Dobbs 1996). A technological aid could be used to hold information concerning an intended action, for example a reminder to take a particular medication for high blood pressure (that is meta-knowledge). The aid could then describe the steps necessary to obtain the medication (for example go to the pharmacy in two days to renew the prescription - planning), alert the individual that the prescription needs to be refilled (that is monitoring), and remind them that the medication is important for controlling blood pressure (that is content recall). The aid could also be used to check whether an action had been taken (for example the prescription had been renewed - output monitoring).

Why it is important to do this review

The long-term nature of paediatric brain injury means that it places considerable burden on the child, family, and society (Linden 2010). The use of technological aids as interventions offers an opportunity to continue treatment in the postacute phase, or even into adulthood, whilst potentially alleviating some of this burden. Effective and timely interventions that employ readily available technology could improve the lives of these children and reduce healthcare costs. However, the evidence for the effectiveness of such interventions has yet to be systematically reviewed.

OBJECTIVES

To assess the effects of technology-based interventions compared to placebo intervention, no treatment, or other types of intervention, on the executive functioning and memory of children and adolescents with acquired brain injury (ABI).

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials, randomised cross-over trials (using only first-phase data, where the order of assignment had been randomised), and cluster-randomised trials.

Types of participants

We included children and adolescents (aged 0 to 19 years) who had sustained an ABI.

Types of interventions

We included studies that evaluated the use of a technology-based intervention on the cognitive functioning of children and adolescents. We define 'technology' here as the incorporation of a device that can store, retrieve, or transmit information. The device may be used under the guidance of a third party (for example healthcare practitioner) or independently. Cognitive functioning is defined here as higher-order processes such as memory and executive functions (that is planning, problem solving, the ability to inhibit or initiate actions). Many of these processes are inter-related and share similar neuroanatomy, but they are theoretically distinct, and deficits in one area may not result in problems with another.

The comparisons were:

- intervention versus placebo;
- intervention versus no treatment;
- intervention versus other types of intervention.

Types of outcome measures

Cognitive processes are those that enable us to make decisions about our lives and include memory, attention, perception, information processing, and executive functioning. The processes most likely to be targeted for intervention using a technological aid include memory and executive functioning. Memory has been defined as the process of encoding, storing, and retrieving information. It enables us to hold information for short periods of time, but also to recall past events, places, and people (Banich 2004). Executive functioning refers to a number of processes that include the ability to control impulses, plan for the future, evaluate performance, organise our personal environment, and regulate behaviour (Stuss 1986).

Due to the compensatory nature of technological aids it would not be expected that changes in cognitive functioning would be apparent, because the aid takes over from damaged processes to support day-to-day functioning. As such, the most appropriate means to determine the success or failure of an aid would be the use of ecologically valid tasks that assessed improvements in functioning, or increased usage of the aid itself.

Primary outcomes

1. Executive functioning
2. Memory

Either of these processes may be tested. Tests usually require initiating actions to complete a task, organising and planning the necessary steps, and monitoring the success or failure of the outcome on a standardised measure. Participants typically receive a

numerical score that is dependent on the type (verbal prompts or physical assistance) and number of cues needed to complete the task.

Some of the most common tests are:

- Children's Kitchen Task Assessment (Rocke 2008);
- School Assessment of Motor and Process Skills (Fisher 1997);
- Children's Cooking Task (Chevignard 2008);
- Behavior Rating Inventory of Executive Function (Gioia 2000);
- Rivermead Behavioural Memory Test for Children (Aldrich 1991);
- any other psychometrically validated tools measuring executive functioning and memory.

3. We also sought (as a separate outcome) to record the type of errors made by participants while completing the assessment tasks (for example control errors, omissions, purposeless actions).

4. If reported, we planned to record the duration of time required to complete the task.

The Children's Kitchen Task Assessment, in Rocke 2008, and the Children's Cooking Task, in Chevignard 2008, have been shown to respectively possess discriminant and concurrent validity (Chevignard 2009), while the School Assessment of Motor and Process Skills (School AMPS), in Fisher 1997, has demonstrable scale and person response validity (Atchison 1998).

Secondary outcomes

1. Frequency of use of the assigned technological aid (process outcome)*
2. Quality of life, as reported by the participant
3. Psychological functioning, including mood (anxiety/depression), self esteem, and self efficacy
4. Social functioning
5. Academic achievement
6. Any other benefits or harms identified by the studies; we described these through a narrative summary.

We intended to classify and analyse outcomes by the time at which measurement was taken following initiation of the intervention. We would group time periods as follows: short term (one month), medium term (over one month to six months), and long term (over six months).

*We determined at the protocol stage to provide data on youths' usage of devices, whilst aware that this was a process outcome rather than necessarily an indicator of effectiveness.

Search methods for identification of studies

In order to reduce publication and retrieval bias we did not restrict our search by language, date or publication status.

Electronic searches

The Cochrane Injuries Group's Information Specialist searched the following:

1. Cochrane Injuries Group Specialised Register (30 September 2015);
2. Cochrane Central Register of Controlled Trials (CENTRAL, the Cochrane Library) (Issue 9 of 12, 2015);
3. Ovid MEDLINE(R), Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily, and Ovid OLDMEDLINE(R) (1946 to 30 September 2015);
4. EMBASE Classic + EMBASE (OvidSP) (1947 to 30 September 2015);
5. PubMed (30 September 2015);
6. CINAHL Plus (1937 to 30 September 2015);
7. PsycINFO (OvidSP) (1806 to 30 September 2015);
8. ISI Web of Science: Science Citation Index Expanded (SCI EXPANDED) (1970 to 30 September 2015);
9. ISI Web of Science: Social Sciences Citation Index (SSCI) (1970 to 30 September 2015);
10. ISI Web of Science: Conference Proceedings Citation Index - Science (CPCI-S) (1990 to 30 September 2015);
11. ISI Web of Science: Conference Proceedings Citation Index - Social Science & Humanities (CPCI-SSH) (1990 to 30 September 2015);
12. ClinicalTrials.gov (www.clinicaltrials.gov) (accessed 30 September 2015);
13. Current Controlled Trials (www.controlled-trials.com/) (accessed 30 September 2015);
14. World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch/) (accessed 30 September 2015).

In addition, the review authors searched the following sources:

1. Theses search (e.g. EThOS, DART, NDLDLT);
 2. National Institute for Health Research (UK) (www.portal.nihr.ac.uk);
 3. UK Clinical Research Network (www.public.ukcrn.org.uk).
- We combined the Ovid MEDLINE strategy with a modified version of the Cochrane Highly Sensitive Search Strategy for identifying randomised trials in MEDLINE (Lefebvre 2011). Search strategies are listed in [Appendix 1](#).

Searching other resources

We screened reference lists of published trials and contacted the authors of all included trials to enquire about other published,

unpublished, and ongoing trials. We searched the following conference proceedings:

- Brain Injury Association (published June 2014);
- International Paediatric Brain Injury Society (published September 2015);
- World Federation for NeuroRehabilitation (published April 2014);
- European Academy of Childhood Disability (published May 2015).

Data collection and analysis

We conducted the review according to the published protocol (Linden 2014).

Selection of studies

One review author (ML) reviewed the titles and abstracts of articles and other publications identified by the search strategy, removing any that were clearly irrelevant. Two review authors (ML and CH) then independently reviewed the resulting list to determine whether the abstracts selected met the inclusion criteria. We then retrieved articles selected based on abstract review in full text for comprehensive review. All authors agreed on the selection of studies for the review.

Data extraction and management

Two review authors (ML and COR) independently extracted the requisite information from the trials by means of a standardised data extraction tool. The effectiveness of this tool was determined by a pilot extraction, which identified problems requiring further refinement. When the tool was deemed valid, ML and COR independently extracted the data. Where possible we sought to document:

- characteristics of the study design;
- type of intervention;
- duration, intensity, and frequency of intervention;
- participant characteristics (e.g. gender, socioeconomic status, age at injury, Glasgow Coma Score (Teasdale 1974), injury severity, description of deficits, age at intervention);
- sample size;
- outcome measures, as described below, and a description of the scale used, range of possible scores, and clinical or practical meaning of scores on the scale;
- effect of the intervention compared to placebo, no treatment, or other types of intervention.

| Outcome | Measurement | Measure for analysis |
|--|--|---|
| Primary outcomes | | |
| Children's Kitchen Task Assessment (Rocke 2008) | 1) Total score 2) Total cues | 1) Mean score & SD 2) Mean score & SD |
| School Assessment of Motor and Process Skills (Fisher 1997) | Process skills total score | Process skills mean score & SD |
| Children's Cooking Task (Chevignard 2008) | 1) Total score 2) Total cues | 1) Mean score & SD 2) Mean score & SD |
| Executive functioning (assessed using any other validated tool) | Total score | Mean score & SD |
| Memory (assessed using any other validated tool) | Total score | Mean score & SD |
| Type of error made when completing the tools listed above | Any | Description of errors explained narratively or presented in a table |
| Duration of time required to complete the task | Total time | Mean score & SD |
| Secondary outcomes | | |
| Use of the assigned technological aid | Total number of sessions completed | Mean number of sessions, range of sessions |
| Quality of life reported by the participant | 1) Total score achieved on the measurement tool used 2) Any | 1) Mean score & SD 2) Any other description summarised narratively or presented in a table |
| Psychological functioning, including mood, self esteem, anxiety, and self efficacy | 1) Total score achieved on the measurement tool used 2) Any | 1) Mean score & SD 2) Any other description summarised narratively or presented in a table |
| Social functioning | 1) Total score achieved on the measurement tool used 2) Any | 1) Mean score & SD 2) Any other description summarised narratively or presented in a table |
| Academic achievement | 1) Total score achieved on the measurement tool used 2) Any | 1) Mean score & SD 2) Any other description summarised narratively or presented in a table |
| Any adverse events/harms identified by the studies | Any | This information will be described through a narrative summary or table |

SD: standard deviation

Assessment of risk of bias in included studies

Two review authors (ML and COR) independently assessed each included study for risk of bias. We assessed domains of potential bias (for example sequence generation, allocation concealment, blinding of participants and personnel, incomplete outcome data, and selective outcome reporting) through use of the 'Risk of bias' assessment tool included in Chapter 8 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We judged each domain in the tool as 'low risk of bias', 'high risk of bias', or 'unclear risk of bias'.

Measures of treatment effect

We planned to use Review Manager software to analyse the data (Review Manager). All included studies reported continuous data, therefore we calculated the standardised mean difference (SMD) for outcomes measured on different scales, with 95% confidence intervals (CI), using the standard error of the mean. For outcomes measured on the same scale, we used the mean difference (MD) with 95% CI. Had we found dichotomous data, we would have described the treatment effect using the risk ratio (RR) with 95% CI.

Unit of analysis issues

The individual child/adolescent was the unit of analysis in each included study.

Dealing with missing data

We assessed all included studies for missing outcome data and made efforts to contact trial authors where missing data was identified.

Assessment of heterogeneity

Two review authors (ML and COR) assessed study heterogeneity. Statistical heterogeneity between studies was assessed through visual inspection of forest plots and use of the I^2 statistic.

Assessment of reporting biases

We identified an insufficient number of studies to allow investigation of reporting biases using a funnel plot.

Data synthesis

It was necessary to pool data for meta-analysis when one trialist provided data for one arm against the control in disaggregated form (that is means and standard deviations were provided separately for

the moderate and severe populations) (Wade 2010). We used the formula described in Section 7.7.3.8 of the *Cochrane Handbook* for this purpose (Higgins 2011).

ML entered data into Review Manager, and COR checked this for accuracy (Review Manager). We calculated the SMD with 95% CI for continuous-outcome data measured on different scales and used a random-effects model. We calculated the MD with 95% CI for continuous-outcome data measured on the same scale and used a random-effects model.

Subgroup analysis and investigation of heterogeneity

We planned to conduct subgroup analysis in relation to age of participants and severity of injury (mild, moderate, and severe), but data were insufficient for this analysis. We have therefore presented results narratively.

Sensitivity analysis

Had we identified sufficient studies, we would have performed sensitivity analysis on allocation concealment and blinding of the outcome assessor; we retain these plans for future updates.

Summary of findings table

We presented results by means of a 'Summary of findings' table (Summary of findings for the main comparison).

RESULTS

Description of studies

Results of the search

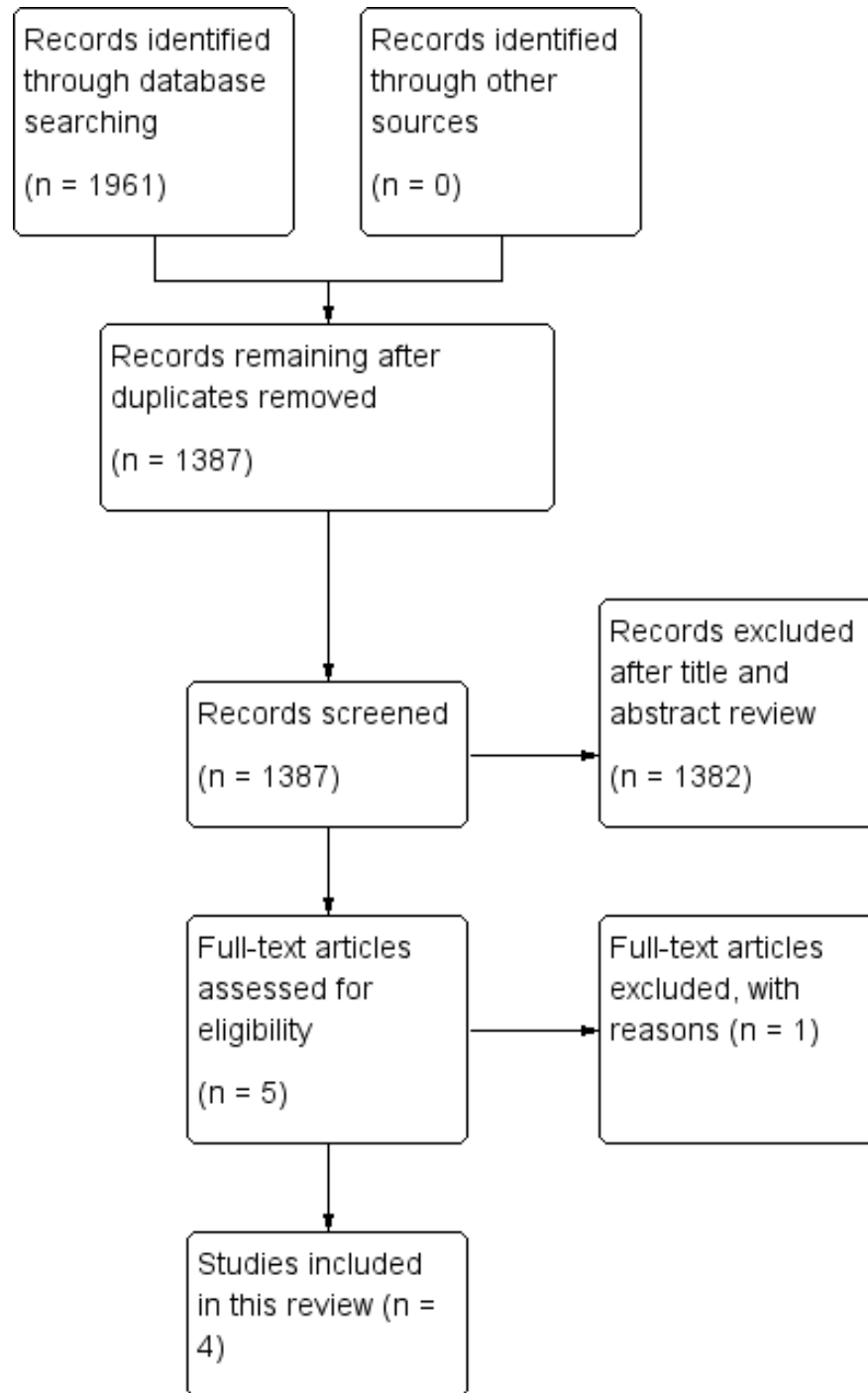
Our most recent search of databases in September 2015 produced 1387 citations from the electronic databases. Searching other resources produced no further references of use. Two review authors (ML and CH) reviewed the search results and selected five published papers for potential inclusion (Kurowski 2013; Thomas-Stonell 1994; Wade 2006; Wade 2010; Wilson 2009). We also identified three additional secondary papers associated with Kurowski 2013 (Arnett 2013; Petranovich 2015; Wade 2014b).

We retrieved the full papers and on closer examination excluded one study (Wilson 2009).

Correspondence with investigators, Linden 2014a and McMullen 2015, led to acquisition of a further four secondary papers related to Kurowski 2013 (Kurowski 2014; Wade 2014a; Wade 2015a; Wade 2015b).

A flow diagram of study selection is presented in Figure 1.

Figure 1. Study flow diagram.



Included studies

We identified four unique trials that met the inclusion criteria. In three studies the intervention groups received the technological aid, while the control groups made use of internet resources (Kurowski 2013; Wade 2006; Wade 2010). In one study the intervention group received the technological aid, while control participants received usual care (Thomas-Stonell 1994). Three participants received unspecified intensive rehabilitation, and three took part in community or school-based programmes. Details are provided in the [Characteristics of included studies](#) tables.

Design

All of the included studies were randomised controlled trials, with the unit of randomisation being the individual child/adolescent. All studies allocated participants to one of two groups: the intervention group (technology-based rehabilitation aid) or control group (internet traumatic brain injury (TBI) resources or usual care).

Sample size

The total number of participants randomised ranged from 12, in Thomas-Stonell 1994, to 132, in Kurowski 2013. Kurowski 2013 was alone in performing a sample size calculation (60 participants per group), which was not met for the intervention group ($n = 57$). However, a secondary paper reports $n = 65$ for the intervention group and $n = 66$ for the control group (Kurowski 2014).

Participants and settings

The included studies analysed data from a total of 206 children and adolescents. Three of the trials were conducted in participants' homes (Kurowski 2013; Wade 2006; Wade 2010), while no information was provided on the setting of the fourth trial (Thomas-Stonell 1994). Trial sample sizes ranged from 12 to 120, and participants were recruited from inpatient rehabilitation units (Wade 2010), paediatric and general medical centres (Kurowski 2013), a children's hospital (Wade 2006), or the source of recruitment was not described (Thomas-Stonell 1994). Participants ranged in age from 5 to 21 years. Three of the studies were conducted in the USA by the same group of authors (Kurowski 2013; Wade 2006; Wade 2010), while the remaining study was undertaken in Canada (Thomas-Stonell 1994).

Interventions

The included studies made the following comparisons.

- Family Problem Solving compared to internet resources (placebo) (Wade 2006).
- Teen Online Problem Solving (TOPS) compared to internet resources (placebo) (Wade 2010).
- Counselor-Assisted Problem Solving (CAPS) compared to internet resources (placebo) (Kurowski 2013).
- TEACHwareTM computer program compared to traditional therapy/community school programs (Thomas-Stonell 1994). The intervention group worked alongside speech and language therapists, occupational therapists, or teachers.

Outcomes

Two studies, Wade 2010 and Kurowski 2013, employed the psychometrically validated Behavior Rating Inventory of Executive Function (BRIEF) (Gioia 2000), and one study, Wade 2006, used a subscale of the Home and Community Social Behavior Scales (HCSBS) to assess executive functioning (Merrell 2001). For the Global Executive Composite of the BRIEF, a high number is suggestive of greater pathology; for the HCSBS, a low number indicates greater pathology.

The fourth study, Thomas-Stonell 1994, employed a standardised assessment battery including tests of recall, attention, problem solving (Semel 1987; Zachman 1989), and a screening module developed with the intervention. The screening module determined whether participants would benefit from the program and measured improvements in skills following remediation.

Outcome measures were self completed by children and adolescents in two studies (Thomas-Stonell 1994; Wade 2006), alongside their primary caregivers (Wade 2010), or solely by the primary caregiver (Kurowski 2013).

Excluded studies

We excluded one paper, which assessed the NeuroPage intervention in children and adolescents, because a high proportion of the participants had developmental problems rather than brain injuries (see [Characteristics of excluded studies](#)) (Wilson 2009).

Risk of bias in included studies

Two review authors (ML and COR) assessed the risk of bias using the domain-based 'Risk of bias' tool of The Cochrane Collaboration (Higgins 2011). We made a judgement of high, low, or unclear risk of bias for all four included studies; this is presented in the [Characteristics of included studies](#) table and summarised in Figure 2.

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

| | Random sequence generation (selection bias) | Allocation concealment (selection bias) | Blinding of participants and personnel (performance bias) | Blinding of outcome assessment (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Other bias |
|---------------------|---|---|---|---|--|--------------------------------------|------------|
| Kurowski 2013 | + | + | - | + | ? | + | + |
| Thomas-Stonell 1994 | ? | ? | - | - | + | - | + |
| Wade 2006 | + | - | - | - | - | ? | + |
| Wade 2010 | + | - | - | - | - | + | + |

Allocation

Kurowski 2013 and Wade 2006 employed a computer program to generate a random sequence for each arm of their trials. Wade 2010 did not report how they randomly stratified participants on the basis of gender and ethnicity. Thomas-Stonell 1994 reported no details on their use of a predetermined randomisation scheme. Only Kurowski 2013 utilised opaque envelopes to conceal allocation. Thomas-Stonell 1994 did not describe allocation concealment, and Wade 2006 and Wade 2010 reported they were unable to conceal allocation to groups. We therefore deemed overall selection bias to be low for Kurowski 2013, unclear for Thomas-Stonell 1994, and high for Wade 2006 and Wade 2010.

Blinding

Kurowski 2013 blinded research assistants to group allocation and assessment, but could not (for obvious reasons) blind participants or their caregivers. Thomas-Stonell 1994 did not describe steps taken to blind participants to group allocation or the researchers to outcome assessment. Wade 2006 and Wade 2010 did not blind the participants or research assistant to group allocation or outcome assessment.

We therefore deemed the risk of performance and detection bias for all studies for this domain as high.

Incomplete outcome data

Thomas-Stonell 1994 reported no dropouts at any point. We therefore judged this study to be at low risk of attrition bias.

Wade 2006 experienced 12% attrition, and there was no indication of intention-to-treat (ITT) analysis, although the investigators maintain this was undertaken. Following randomisation, one child was excluded on the basis of injury severity. Two families assigned to the intervention condition dropped out before follow-up, while another family could not be contacted at follow-up. Two further families in the intervention group failed to complete five or more sessions. No participants dropped out of the control condition. Outcome data appear to have been analysed on a per-protocol basis. As all dropouts came from the intervention group, we assessed this study as being at high risk of attrition bias.

Wade 2010 experienced 14.6% attrition. Four families in the intervention group and one in the control group dropped out. The authors appear to have analysed outcome data on a per-protocol basis. Again, due to differential dropout (80% in the intervention group), we deemed the risk of attrition bias as high.

Kurowski 2013 experienced 9.1% attrition overall. In the active treatment arm, one family did not complete baseline assessment, two dropped out following assessment, two dropped out after the first visit, and three were lost to follow-up (total = 8 participants).

In the control group, one participant did not complete baseline assessment, and a further three were lost to follow-up (total = 4 participants). Reasons for drop-out were provided for four out of the eight families assigned to the intervention group; no reasons for drop-out were provided for people in the control group. Whilst authors of Kurowski 2013 stated they would perform analysis by intention to treat (n = 132), they failed to include all randomised participants in the analyses (n = 120) and in a further paper related to this study, Wade 2014a (n = 118). In subsequent papers, Kurowski 2014, Wade 2015a, and Wade 2015b, it would appear ITT was performed ("One hundred thirty-two participants were randomized to the CAPS [Counselor-Assisted Problem Solving] (n = 65) or the IRC [internet resource comparison] (n = 67) groups (Figure 1). The CONSORT diagram (Figure 1) shows the number unavailable for follow-up in each group at the 6-, 12-, and 18-month assessments. The final analysis included 65 CAPS and 66 IRC participants." Kurowski 2014 pE5-6); investigators did not report means and standard deviations for long-term outcome data and have not responded to requests to provide this at time of preparation of this manuscript (10 July 2015 personal correspondence). We therefore judged this study as being at unclear risk of attrition bias.

Selective reporting

We did not find registered protocols for Thomas-Stonell 1994 and Wade 2006. Thomas-Stonell 1994 failed to report means and standard deviations for all outcomes. The P values for findings that were not statistically significant were not reported. We contacted the lead author to provide the missing data but had received no response at the time the final draft of this review was prepared. Wade 2006 stated that analysis would be by intention to treat. However, 46 families underwent randomisation, with 40 families included in subsequent analyses. We deemed risk of selective reporting bias as unclear.

Trial protocols were available in study registers from Kurowski 2013 and Wade 2010.

We found some discrepancies in reporting. Kurowski 2013 initially stated their inclusion criteria as adolescents aged 12 to 18 years who had sustained a moderate to severe injury. The published manuscript reports a narrower age range (12 to 17 years) and a wider range of injury severity (mild, moderate, and severe). In addition, Kurowski 2013 divided their sample into older and younger adolescents but failed to report the numbers in each group. However, these numbers were available (older adolescents aged 14 to 17 years, n = 74; younger adolescents aged 12 to 14 years, n = 56) in a subsequent publication reporting long-term data from the same study (Kurowski 2014). Kurowski 2013 stated that they sought information from the control group on the internet TBI resources

accessed, however these data are not reported. This information is provided in a subsequent publication (Wade 2014a). Given that none of these anomalies are likely to bias results, we assessed this criterion as 'low'.

Wade 2010 initially reported that children whose injury occurred more than 12 months prior to study commencement would be excluded, and those who had an overnight hospital stay would be included. The published manuscript increased the first criterion to 18 months and failed to mention the second. In addition, there was no explanation for why one family consented to participate but then chose not to complete baseline measurement. As these deviations were minor, we deemed the risk of selective reporting bias for this study to be low.

Other potential sources of bias

We identified no other sources of bias in the included studies.

Effects of interventions

See: [Summary of findings for the main comparison Technological aid compared to internet resource for children or adolescents with acquired brain injury](#)

We included data from three studies in meta-analysis of one primary outcome, and data from two studies in meta-analysis of one secondary outcome. We compared a technology-based intervention versus use of internet resources on TBI (conceptualised as 'placebo') (194 participants) for executive functioning. Thomas-Stonell 1994 did not provide means and standard deviations for measures of attention, organisation, and problem solving and was not included in meta-analysis; this was also the only study to provide data on the second primary outcome of memory, albeit not in a 'useable' form, and data therefore did not warrant meta-analysis. We compared the technology-based intervention versus use of internet resources on TBI (158 participants) for the secondary outcome mood (anxiety/depression).

Primary outcomes

Executive functioning

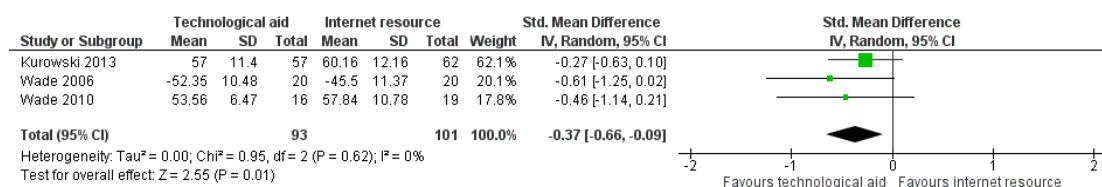
Post-treatment data

We included three studies in the meta-analysis: Kurowski 2013 (n = 120), Wade 2006 (n = 40), and Wade 2010 (n = 35). Thomas-Stonell 1994 (n = 12) did not provide data for components of executive functioning (for example attention, organisation, and problem solving).

Kurowski 2013 and Wade 2010 both used parent report versions of the Behavior Rating Inventory of Executive Function (BRIEF), which indicates better executive functioning with lower score. From these, we extracted data from the Global Executive Composite (GEC) of the BRIEF, which represents an overall total score of executive functioning. Raw scores, ranging from 86 to 258, are converted into T scores based on established norms. T scores over 65 indicate clinically important levels of executive dysfunction. Following personal correspondence with authors of Kurowski 2013, we established that some means and standard deviations provided in the original published paper were inaccurate and that an erratum notice (as yet unpublished) would appear in due course. We used the corrected figures for meta-analysis for this outcome (Kurowski 2015). Wade 2006 measured self management, a component of executive functioning, via the Home and Community Social Behavior Scales (HCSBS) (Merrell 2001). High scores on the HCSBS indicate improved self management; we therefore changed the polarity of data whilst entering into Review Manager. Self management, as measured by the HCSBS, is comparable to aspects of the Behavioral Regulation Index, a sub-component of the BRIEF GEC.

Results for this outcome were standardised mean difference (SMD) -0.37, 95% confidence interval (CI) -0.66 to -0.09, showing some benefit for the intervention group. (As there is no 'gold standard' measure in the field, we have not translated the SMD back to any particular scale). This result is thought to represent only a small to medium effect size (using Cohen's rule of thumb, where 0.2 is a small effect, 0.5 a medium one, and 0.8 or above a large effect); this is unlikely to have a clinically important effect on the child. There was no statistical heterogeneity ($I^2 = 0\%$; Analysis 1.1 and Figure 3).

Figure 3. Forest plot of comparison: I Technological aid vs internet resource comparison, outcome: I.1 Executive functioning (various measures).



Long-term (18-month) data

The largest study presented long-term data (Kurowski 2013), but the data were not provided in the form of means and standard deviations, nor were they provided for the whole sample (Kurowski 2014). We have requested the full dataset from the study authors, but they have not been forthcoming at time of preparation of this manuscript (Kurowski 2015). The authors did report data by age (children aged 12 to 14 are described as “younger teens”, while those 14 to 17 are “older teens”). (“Within the younger group (aged 12-14 years), no differences between the CAPS and the IRC groups were seen at baseline ($\beta = -0.15$; $P = .53$) or at 6 ($\beta = -0.23$; $P = .8$), 12 ($\beta = 0.04$; $P = .88$), or 18 ($\beta = 0.13$; $P = .62$) months after the intervention. Within the older group (aged > 14 to 17 years), no differences were seen at baseline between the CAPS and IRC groups ($\beta = -0.34$; $P = .11$) but were seen at 6 ($\beta = -0.40$; $P = .05$), 12 ($\beta = -0.46$; $P = .03$), and 18 ($\beta = -0.52$; $P = .02$) months after the intervention.” Kurowski 2014 pE5). The study authors suggest the intervention is more effective in older adolescents at long-term follow-up. However, all these results should be interpreted with caution as there are too few people included in the analyses to provide reliable results, and P values from small samples are statistically unreliable (due to Type 1 and 2 error).

Memory

As only one included study assessed memory, we did not perform meta-analysis. Thomas-Stonell 1994 (n = 12) examined the use of a computer program intended for the remediation of cognitive communication skills, memory, attention, and problem solving in adolescents with TBI. Twelve participants (mean age 16.75 years) were randomly assigned to either the TEACHwareTM intervention or the usual-care control. A number of measures explored components of language, memory, and executive functions (see Characteristics of included studies). Analysis of covariances were chosen to compare the groups across time, whilst controlling for group differences at baseline. Only data from the Recalling Sentences subtest (assessing memory) and The Adolescent Word Test - task A-brand names (assessing problem solving/reasoning) together with various language measures were reported. The results showed a statistically significant difference between the intervention and control groups in regards to memory ($P = 0.03$) and problem solving ($P < 0.001$), but these results should be interpreted with caution as there are too few people included in the analyses to provide reliable results (P values from small samples are

statistically unreliable (due to Type 1 and 2 error)). In addition, measures of central tendency and dispersion were not provided for these findings.

Type of errors made by participants

No data supplied by any investigator for this outcome.

Duration of time required to complete the task

No data supplied by any investigator for this outcome.

Secondary outcomes

Use of the assigned technological aid

Two studies (160 participants) reported on the number of sessions undertaken (range 0 to 13 in Kurowski 2013 and 1 to 24 in Wade 2006). (“...there were significant negative correlations between the number of sessions completed and both child behavior problems (-.59) and parental distress (-.60) at baseline, suggesting that families with more problems at baseline completed fewer sessions.” Wade 2006 p185)

Quality of life reported by the participant

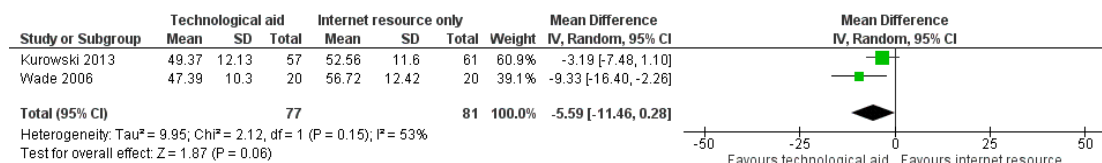
No data supplied by any investigator for this outcome.

Psychological functioning including mood (anxiety or depression), self esteem, and self efficacy

Post-treatment data

We pooled data from Wade 2006 (n = 40) and a secondary paper associated with Kurowski 2013 (n = 118) for this outcome, using a measure related to both anxiety and depression (the internalising subscale of the Child Behavior Checklist (CBCL)) (Achenbach 2000). Results showed no difference (mean difference (MD) - 5.59, 95% CI -11.46 to 0.28) in internalising problems on the CBCL between treatment groups. Heterogeneity was moderate ($I^2 = 53\%$). These results suggest there is no evidence that children and adolescents in receipt of technology-based interventions had a reduction in their levels of anxiety or depression (see Analysis 1.2 and Figure 4).

Figure 4. Forest plot of comparison: I Technological aid vs internet resource comparison, outcome: I.2 CBCL Internalising subscale.



Long-term (18-month) data

In a secondary paper from the [Kurowski 2013](#) study, data for anxiety or depression (internalising problems) are provided, albeit not in the form of means and standard deviations (SDs), nor are they provided for the whole sample ([Wade 2015b](#)).

(“Among high school participants, the CAPS group demonstrated a steady decrease in internalizing problems over time (from a high of 53.4 at baseline to a low of 49.0 at visit 4), whereas the average for the IRC group remained relatively flat (baseline score = 55.4 to visit 4 score = 54.6).... CAPS high school participants were significantly better at visit 4 than their IRC counterparts ($t = -2.06$; $p = 0.04$). Treatment differences for middle school participants were not significant. Both groups reported a decrease in internalizing problems over time.” [Wade 2015b](#) pp970-1)

No data were reported by any investigator for outcomes of self esteem or self efficacy.

Social functioning

One study (40 participants) reported on social functioning. [Wade 2006](#) reported an improvement in social competence for the intervention group that was not statistically significant (HCSBS Social Competence) total T score. The intervention group mean was 53.15 (SD 9.89) compared to the control group mean of 45.50 (SD 11.50).

Academic achievement

No data supplied by any investigator for this outcome.

Adverse events

Insufficient studies reported on adverse events to conduct analysis. One study ($n = 120$ participants) recorded adverse events and reported that there were none ([Kurowski 2013](#)).

Subgroup analyses

Investigators of all three studies included in this review conducted and presented data from their own subgroup analyses.

Age

Two studies investigated age but did not provide data in relation to group numbers ([Kurowski 2013](#); [Wade 2006](#)).

One study suggested that children in the intervention group aged 11 to 16 years made greater improvements in executive functioning than similarly aged children in the control group ([Wade 2006](#)).

A second study presented data on age and showed that older (> 14 to 17 years) adolescents in the intervention group made greater improvements in executive functioning than adolescents in the age-matched control group (intervention group change score -4.78 (6.66), control group change score -0.86 (5.98)) ([Kurowski 2013](#)). Executive functioning of younger (12- to 14-year-old) adolescents in the intervention group decreased (change score 1.40 (9.46)). Long-term data from a secondary paper showed a small lasting effect for older adolescents at 6, 12, and 18 months ([Kurowski 2014](#)). No means or SDs were presented for this outcome.

Memory and executive functioning by severity of TBI

One study reported data according to severity of TBI and showed that among adolescents with severe TBI, those in the intervention group made greater improvements compared to those in the control group (intervention group 54.29 (12.55), control group 62.43 (15.75)) ([Wade 2010](#)). Among adolescents with moderate TBI, there was no difference between participants in the intervention and control groups (intervention group 53.00 (8.82), control group 55.17 (13.00)). No studies provided data on severity of TBI in relation to memory.

DISCUSSION

Summary of main results

Results suggest that technological aids may be useful in the rehabilitation of executive functions in adolescents with brain injury. We based these findings on three of the four included studies, which examined only executive functions, as well as narrative findings of a fourth study, which assessed outcomes on memory.

The three studies (n = 194) that investigated executive functions utilised a web-based problem-solving approach that involved a counsellor or clinical trainee. Meta-analysis of these studies showed that online interventions were effective in improving executive functioning for TBI (Kurowski 2013; Wade 2006; Wade 2010). However, the effect size (-.037) is considered to be small to medium, and is therefore unlikely to be of clinical importance to the child; the quality of evidence according to GRADE was very low.

Two studies (n = 155) assessed only adolescents (11 to 18 years) (Kurowski 2013; Wade 2010), whilst the third (n = 40) included a sample of younger (5 to 10 years) and older children (11 to 16 years) (Wade 2006).

The one study (n = 12) that investigated memory included this in the context of cognitive communication skills training that included aspects of executive functions (Thomas-Stonell 1994). The findings indicated the potential for a computer program to improve memory (P = 0.03) and problem solving (P < 0.001).

Secondary outcomes in this review including quality of life, self esteem, mood, self efficacy, and academic achievement were not well-addressed in the included studies. Wade 2006 and a secondary paper associated with Kurowski 2013 assessed changes in anxiety and internalising behaviour. Meta-analysis of these papers suggested no evidence for an effect in reducing anxiety and internalising behaviours for adolescents who received online interventions; we rated the quality of evidence as very low. Kurowski 2013 reported that no adverse events occurred as a result of their trial. Kurowski 2013 and Wade 2006 also reported on use of the intervention, with figures ranging from 0 to 24 sessions, but it is at present unclear whether a dose response can be detected.

Three of the four studies contained small numbers (12 to 40) of heterogeneous participants, and so their results should be interpreted with caution (Thomas-Stonell 1994; Wade 2006; Wade 2010). One study employed a multicentre approach to achieve a larger sample of 120 participants (Kurowski 2013).

Overall completeness and applicability of evidence

All of the included studies utilised the involvement of a therapist who delivered some support or training. The presence of a therapist introduces the possibility that the intervention was effective due to contact with a professional rather than the use of the technology-based intervention. In addition, one of the main suggested benefits of technology-based interventions is said to be their reduced healthcare costs. The introduction of a therapist in the included studies would clearly have cost implications if these interventions were to be implemented on a larger scale.

The three online interventions took place in the family home (Kurowski 2013; Wade 2006; Wade 2010). This has the advantage of greater convenience for families who may live far removed from healthcare services; however, the supply of computer equipment

and high-speed internet access suggests these interventions may be limited to regions of the world and to families who have access to these resources. Wade 2006 suggests that these interventions may be more effective for children from poorer backgrounds, who may not have access to such resources as a matter of course.

No information was provided on the setting of the only study to use a stand-alone computer program (Thomas-Stonell 1994). While such a program could conceivably be operated in the home, thus reducing travel and healthcare costs, the involvement of a therapist would suggest home visits, which would increase costs. Again, this intervention would be limited to families who could afford adequate computing facilities.

All of the included studies were conducted in North America, with three of these originating from the same team of researchers (Kurowski 2013; Wade 2006; Wade 2010). Additional research is needed to extend these findings to a range of international contexts and resource levels.

Quality of the evidence

The four trials randomised 206 children and adolescents, with sample sizes ranging from 12 to 120 participants. We assessed the largest study, Kurowski 2013, as having the lowest risk of bias by means of the domain-based 'Risk of bias' tool of The Cochrane Collaboration (Higgins 2011). The three remaining studies had higher or unclear risk of bias in three of the seven domains. The use of opaque envelopes in Kurowski 2013 to conceal allocation reduced the potential for selection bias, however all studies were unable to blind participants to group allocation, and only one, Kurowski 2013, was able to conceal allocation to assessors, suggesting the presence of detection and performance biases.

Given the novel approach taken with technology-based interventions, it is extremely difficult to blind participants and assessors to treatment. Three of the included studies incorporated the use of internet resources as a placebo control for their participants (Kurowski 2013; Wade 2006; Wade 2010). Whilst preferable to no activity, both the participants and assessors would be aware that this did not constitute the intervention group. Kurowski 2013 did take steps to blind assessors to group allocation. However, if future studies were to compare contrasting types of technology-based interventions, this might further reduce the chance of performance and detection bias.

Overall, the quality of evidence using GRADE criteria was very low. This means future research is very likely to change the estimate of effect.

Potential biases in the review process

We closely followed the procedures outlined in our protocol, which described the steps we would take to minimise bias. These included trial screening, data extraction, and assessment of bias by

two review authors acting independently. Any instances where our review deviates from the published protocol have been described below. Our search strategy was developed and conducted by an experienced information specialist within the Cochrane Injuries Group, thus we are confident we have identified all relevant studies. In addition, we contacted the lead authors of included studies to enquire whether they were aware of any further as yet unpublished trials. However, it is still possible that we may have missed some published or unpublished work.

Agreements and disagreements with other studies or reviews

This is the first published systematic review of trials comparing the use of technological aids for the rehabilitation of memory and executive functions in children and adolescents.

AUTHORS' CONCLUSIONS

Implications for practice

We found limited evidence to support the use of technology-based interventions for the rehabilitation of memory and executive functions in children and adolescents with brain injury.

Implications for research

This review shows the potential for using technology-based interventions for older children with acquired brain injury. Three of the included studies employed the internet as a means to deliver problem-solving, communication, and behavioural-management training in the home setting. Receiving such training at home is undoubtedly convenient for the families and likely results in reduced costs to both families and healthcare providers. However, it is less clear what advantage using technology in this way has over face-to-face contact with a healthcare provider. These studies also employed an individual who provided clinical input to the intervention. This individual helped with certain aspects of the training and provided support; however, it is difficult to know whether the success of such work was due entirely to the technological program delivered or to the characteristics of the person. One study removed human involvement entirely by using computer software to deliver training on memory and communication. The type of rehabilitation, method of delivery, and sophistication of the technology must be carefully considered in any new intervention to ensure its effectiveness.

The increasing sophistication of technology means that new interventions are continually under development, and we must ensure that they are rigorously tested. Researchers should be mindful that the technology must add something over and above existing

practice. Greater collaboration between computer scientists, researchers, and clinicians could lead to advances in the use of technology that have tangible benefits for rehabilitation.

Older children and adolescents tended to benefit more from interventions included in this review than younger children. Additional work needs to explore the use of technology adapted for use with younger children. Seeking the input of this age group in the design and delivery of future interventions would ensure a more tailored bottom-up approach that may have a greater chance of success.

A primary rationale for using technology-based interventions is the reduction in personnel costs and other resources associated with healthcare provision. Future trials should include an economic evaluation component to determine whether the use of technology has the potential to reduce costs. In addition, we tend to believe that delivery in the home is preferable for families over travelling to a hospital appointment. It would be important to determine whether families prefer a face-to-face or online consultation.

None of the included trials used an ecologically valid measure of executive functioning (for example Children's Kitchen Task Assessment) (Rocke 2008). Instead, they utilised paper-and-pencil tests which, while psychometrically valid, are arguably a less effective way of measuring executive functions. Ecological measures allow for greater sensitivity over pencil-and-paper tests by providing a closer approximation to the demands of everyday living (Chevignard 2008). Future trials should therefore seek to use an ecological measure of executive function.

All included studies contained small numbers of participants (12 to 120). The largest trial employed a multicentre approach to recruitment, which allowed for a larger sample. Greater collaboration between researchers across sites could enable further multicentre studies in order to boost recruitment. Future studies should utilise sample size calculations and seek to increase the sample size.

Future authors of randomised controlled trials should ensure that their research is published in line with the Consolidated Standards of Reporting Trials (CONSORT) statement to aid clarity and allow readers to assess the validity of their results (Schulz 2010). Additional research design considerations include adequate explanation of participant randomisation, blinding of participants and assessors, analysis by intention to treat, and accurate reporting of statistical results.

ACKNOWLEDGEMENTS

We would like to thank Emma Sydenham, Managing Editor, Cochrane Injuries Group (CIG), Deirdre Beecher, Information Specialist CIG, and Jane Dennis, Editor CIG for their guidance and help with this review.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Kurowski 2013

| | |
|---------------|---|
| Methods | Multicentre randomised controlled trial |
| Participants | <p>Setting: participants' homes</p> <p>Inclusion criteria: adolescents aged 12 to 17 years with mild to severe TBI.</p> <p>Exclusion criteria: nonblunt trauma, primary language other than English, premorbid history of intellectual disability, history of child abuse, insufficient recovery to allow participation in the study, history of parental or child psychiatric hospitalisation within 1 year before enrolment, family residence in an area without high-speed internet access, child residence outside family home, resided > 3 hours from study site</p> <p>Participant numbers: 132 were randomly assigned, 86 males and 46 females (44 males in CAPS, 42 males in IRC). 81 participants with severe TBI. 8 withdrew from CAPS intervention group, 4 withdrew from IRC control group; 120 analysed. Recruitment occurred 1 to 6 months following injury</p> |
| Interventions | <p>CAPS intervention was web based and addressed problem solving, communication, and self regulation in a family context, over a 6-month period (n = 57). This comprised 6 sessions in the first 3 months, with 4 supplemental sessions in months 4 and 5, if families had persistent concerns. All families received a final session with the counsellor in month 6</p> <p>The IRC group utilised online brain injury websites for approximately 1 hour per week (n = 63)</p> <p>Families in both groups received a computer, web camera, and high-speed internet access</p> |
| Outcomes | <p>Primary outcome: Global Executive Composite (GEC) of the Behavior Rating Inventory of Executive Function (BRIEF), administered to parents. All other BRIEF subscales. The Behavioral Regulation Index (BRI) including Inhibit, Shift, Emotional Control and subscales of the Metacognition Index (MI) including Initiate, Working Memory, Plan/Organize, Organization of Materials and Monitor</p> <p>Secondary outcomes: No adverse events. Mean number of sessions completed in the CAPS group was 7.23 (SD: 2.99, range: 0 to 13). Child Behavior Checklist (CBCL) Internalising Problems total T score* (Achenbach 2000).</p> <p>Other outcomes not included in this review: CBCL externalising problems and total behavior problems*. CBCL subscales of attention, aggression, attention-deficit hyperactivity disorder, and conduct disorder*. Processing Speed Index from the Wechsler Intelligence Scale for Children, Fourth Edition or the Wechsler Adult Intelligence Scale, Fourth Edition* (Wechsler 2004; Wechsler 2008). The Service Assessment for Children and Adolescents* (Slomine 2006). Child and Adolescent Functional Assessment Scale (CAFAS)* (Hodges 2000). Global Severity Index (GSI) of the Symptom Checklist-90-R* (Derogatis 1994). Center for Epidemiologic Studies Depression Scale* (Radloff 1977). Caregiver Self-Efficacy Scale* (Boothroyd 1997). California Verbal Learning Test* (Delis 1994). School competency subscale of the CBCL* (Achenbach 2000).</p> |

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| Notes | <p>Source of funding: Colorado Traumatic Brain Injury Trust Fund Research Program, Colorado Department of Human Services, Division of Vocational Rehabilitation, Traumatic Brain Injury Program. Also supported in part by the National Institutes of Health (NIH) grant R01-MH073764 from the National Institute of Mental Health and NIH grant 2K12 HD001097-16</p> <p>*Outcomes reported in secondary papers</p> | |
| Risk of bias | | |
| Bias | Authors' judgement | Support for judgement |
| Random sequence generation (selection bias) | Low risk | Randomisation was stratified by gender and race to ensure balance. A statistics package calculated block sizes for each of the randomisations |
| Allocation concealment (selection bias) | Low risk | Sealed envelopes were used |
| Blinding of participants and personnel (performance bias) All outcomes | High risk | Unable to conceal assignment from families/participants. A web camera was provided to blind research assistants to allocation |
| Blinding of outcome assessment (detection bias) All outcomes | Low risk | Assessments were performed without knowledge of group allocation |
| Incomplete outcome data (attrition bias) All outcomes | Unclear risk | Recruitment and attrition (9%) were reported. Reasons for drop-out were provided for 4 out of the 8 families assigned to the intervention. No reasons for drop-out were provided for 4 families in the control group. Intention-to-treat analysis was reported, however not all randomised participants were included in the analysis |
| Selective reporting (reporting bias) | Low risk | Protocol was registered as NTC00409448 and states wider inclusion criteria for age (12 to 18 years) than the published manuscript (12 to 17 years). In addition, the protocol states that severity will be limited to moderate to severe TBI, however the paper reports mild, moderate, and severe inclusion criteria |
| Other bias | Low risk | None apparent |

| | |
|---------------|---|
| Methods | Randomised controlled trial |
| Participants | <p>Setting: not described</p> <p>Inclusion criteria: adolescents aged 12 to 21 years with cognitive-communication deficits secondary to TBI. Minimum of 7 years schooling in English prior to injury and achieved academic success if English was a second language. Demonstrated comprehension of basic syntax and linguistic concepts. Intact expressive language skills. Recovery to stage 7 or 8 of the Rancho Los Amigos Orientation Scale. Minimum of 3 months postinjury</p> <p>Exclusion criteria: learning or academic difficulties. Scoring less than 15% or greater than 85% on the TEACHwareTM screening module. Those with no major cognitive-communication deficits</p> <p>Participant numbers: 12 were randomly assigned, 3 males and 9 females (2 males and 4 females TEACHwareTM, 1 male and 5 females control). Severity ranged from no loss of consciousness to 6 weeks</p> |
| Interventions | <p>TEACHwareTM is a computer-based intervention that addresses the remediation of higher-level cognitive-communication deficits. Focusing on the following areas: attention, memory/word retrieval, comprehension of abstract language, organisation, and reasoning/problem-solving skills (n = 6). Frequency of these hour-long sessions varied but averaged 2 per week for 8 weeks</p> <p>The control group received usual care (n = 6)</p> |
| Outcomes | <p>Primary outcomes:</p> <p><i>Attention:</i> The paced auditory serial-addition task (Gronwall 1977).</p> <p><i>Word retrieval:</i> Expressive One-Word Picture Vocabulary Test - Upper Extension (Gardiner 1979), Clinical Evaluation of Language Fundamentals-Revised - Word Associations subtest (Semel 1987), The Adolescent Word Test - task B-synonyms (Zachman 1989).</p> <p><i>Memory:</i> Clinical Evaluation of Language Fundamental-Revised - Recalling Sentences subtest (Semel 1987).</p> <p><i>Organisation:</i> Clinical Evaluation of Language Fundamental-Revised - Sentence Assembly subtest (Semel 1987), Test of Language Competence - Recreating Sentences (Wiig 1985).</p> <p><i>Problem solving/reasoning:</i> Test of Language Competence - Making Inferences (Wiig 1985), The Adolescent Word Test - task A-brand names and task B-synonyms (Zachman 1989).</p> <p>Secondary outcomes: None reported.</p> <p>Other outcomes not included in this review:</p> <p><i>Comprehension:</i> The Peabody Picture Vocabulary Test-Revised; forms L or M (Dunn 1981), The Adolescent Word Test - task C-signs of the times and task D-definitions (Zachman 1989), Test of Language Competence - Understanding Metaphoric Expressions and Understanding Ambiguous Sentences (Wiig 1985), Clinical Evaluation of Language Fundamental-Revised - Listening to Paragraphs subtest (Semel 1987).</p> <p><i>Broad language measures:</i> The Adolescent Word Test (Zachman 1989), Test of Language Competence (Wiig 1985)</p> |
| Notes | <p>Source of funding: The Hospital for Sick Children Foundation, the Easter Seal Research Institute, and Apple Canada</p> |

| <i>Risk of bias</i> | | |
|---|---------------------------|--|
| Bias | Authors' judgement | Support for judgement |
| Random sequence generation (selection bias) | Unclear risk | Eligible participants were assigned to either the control or remediation group based on a predetermined randomisation scheme. This scheme is not explained |
| Allocation concealment (selection bias) | Unclear risk | None described |
| Blinding of participants and personnel (performance bias) All outcomes | High risk | Participants could not be blinded. No information about personnel |
| Blinding of outcome assessment (detection bias) All outcomes | High risk | None described |
| Incomplete outcome data (attrition bias) All outcomes | Low risk | Recruitment was reported, no attrition |
| Selective reporting (reporting bias) | High risk | No evidence of a published protocol could be found. Authors were selective in the reporting of raw data |
| Other bias | Low risk | None apparent |

Wade 2006

| | |
|---------------|---|
| Methods | Randomised controlled trial |
| Participants | <p>Setting: participants' homes</p> <p>Inclusion criteria: children and adolescents aged 5 to 16 years sustaining moderate to severe TBI in previous 24 months. Live at home and speak English</p> <p>Exclusion criteria: nonblunt trauma or history of child abuse.</p> <p>Participant numbers: 42 families were randomly assigned, 2 families failed to complete 5 or more sessions and were excluded from analysis. 40 families were retained (20 FPS, 20 IRC). 23 males and 17 females (11 males FPS, 12 males IRC). Mean lowest GCS for FPS 12.18 compared to 10.55 IRC. Recruitment occurred 24 months postinjury</p> |
| Interventions | <p>The online FPS intervention comprised 14 separate sessions. 8 core sessions covered issues such as problem solving, communication, and antecedent behaviour management skills. 6 supplemental sessions addressed stress management, working with the school, sibling concerns, anger management, pain management, and marital communication (n = 20)</p> <p>The IRC group utilised online brain injury websites in addition to usual care (n = 20)</p> <p>Families in both groups received a computer, 19-inch monitor, inkjet printer, and high-speed internet access</p> |

| | | |
|---|---|--|
| Outcomes | <p>Primary outcomes: Home and Community Social Behavior Scales (HCSBS) Self-Management/Compliance total T score (measure of executive function)</p> <p>Secondary outcomes: Child Behavior Checklist (CBCL) Internalising Problems total T score. HCSBS Social Competence total T score. Sessions completed ranged from 1 to 24</p> <p>Other outcomes not included in this review: CBCL Behavior Problems total T score, CBCL Externalising Problems total T score; HCSBS (Merrell 2001). Peer total T score. Problem Solving and Communication subscales from the Family Assessment Device (Miller 1985)</p> | |
| Notes | <p>Source of funding: National Institutes of Health Grant HD40942-02, National Council on Medical Rehabilitation Research</p> | |
| Risk of bias | | |
| Bias | Authors' judgement | Support for judgement |
| Random sequence generation (selection bias) | Low risk | Assignment to intervention and control conditions was accomplished by use of a computer program |
| Allocation concealment (selection bias) | High risk | Neither the participants nor the research assistant were blind to allocation |
| Blinding of participants and personnel (performance bias) All outcomes | High risk | Participants and research assistant were not blinded |
| Blinding of outcome assessment (detection bias) All outcomes | High risk | Research assistant was not blinded |
| Incomplete outcome data (attrition bias) All outcomes | High risk | Recruitment and attrition (12%) were reported. 2 families assigned to the intervention condition dropped out before follow-up, 1 additional family could not be contacted at follow-up. 2 further families in the intervention group failed to complete 5 or more sessions. No participants dropped out of the control group |
| Selective reporting (reporting bias) | Unclear risk | Outcomes relevant to this area were reported, as were clear instructions on interviewer training. However, we could find no evidence of a published protocol |
| Other bias | Low risk | None apparent |

| | | |
|---|--|---|
| Methods | Randomised controlled trial | |
| Participants | <p>Setting: participants' homes</p> <p>Inclusion criteria: adolescents aged 11 to 18 years sustaining moderate to severe TBI in previous 18 months</p> <p>Exclusion criteria: primary language was not English, history of child abuse, adolescent or primary caregiver had been hospitalised for psychiatric reasons before injury, lack of communication skills that would prevent participation</p> <p>Participant numbers: 42 families were randomly assigned, 41 completed baseline measurement. 1 family was excluded due to diminished capacity. 40 families were retained (20 TOPS, 20 IRC). 4 withdrew from TOPS intervention group, 1 withdrew from IRC control group. 17 males and 18 females (6 males TOPS, 11 males IRC); 35 analysed. Clinical computed tomography and magnetic resonance imaging showed normal imaging (2 TOPS, 5 IRC), mild abnormalities (3 TOPS, 2 IRC), moderate abnormalities (2 TOPS, 4 IRC), and severe abnormalities (9 TOPS, 8 IRC). Recruitment occurred 18 months following injury</p> | |
| Interventions | <p>TOPS intervention was web based and addressed stress management, problem solving, planning and organisation, communication, and self regulation in a family context over a 6-month period (n = 16). This comprised 10 core sessions on the above topics and 6 supplemental sessions on the stressors and burdens of individual families</p> <p>IRC group utilised online brain injury websites for approximately 1 hour per week (n = 19)</p> <p>Families in both groups received a computer, web camera, and high-speed internet access if they did not already have them</p> | |
| Outcomes | <p>Primary outcome: Global Executive Composite (GEC) of the Behavior Rating Inventory of Executive Function (BRIEF) and BRIEF self report, administered to parents and adolescents, other BRIEF subscales including the Behavioral Regulation Index (BRI) and the Metacognition Index (MI)</p> <p>Secondary outcomes: None reported</p> | |
| Notes | <p>Source of funding: National Institute of Disability and Rehabilitation Research, US Department of Education and Emergency Medical Services grant 105030 from the Ohio Department of Safety</p> | |
| <i>Risk of bias</i> | | |
| Bias | Authors' judgement | Support for judgement |
| Random sequence generation (selection bias) | Low risk | Randomly assigned based on stratification of gender and race/ethnicity to ensure comparable numbers in each group |
| Allocation concealment (selection bias) | High risk | Neither the participants nor the research assistant were blind to allocation |

Wade 2010 (Continued)

| | | |
|---|-----------|--|
| Blinding of participants and personnel (performance bias) All outcomes | High risk | Unable to blind participants or research assistant to allocation |
| Blinding of outcome assessment (detection bias) All outcomes | High risk | Research assistant was not blinded to outcome assessment |
| Incomplete outcome data (attrition bias) All outcomes | High risk | Recruitment and attrition (14.6%) were reported. 4 families in the intervention group and 1 in the control group dropped out. Authors did not perform analysis on an intention-to-treat basis |
| Selective reporting (reporting bias) | Low risk | Protocol was registered as NTC00409058 and states that child whose injury occurred more than 12 months previously would be excluded from the study. The published paper included those injured in the previous 18 months. The protocol also suggests an overnight hospital stay as an inclusion criterion, which is absent from the published manuscript. No explanation as to why 1 family consented to participate but did not complete baseline measurement |
| Other bias | Low risk | None apparent |

CAPS: Counselor-Assisted Problem Solving
 FPS: Family Problem Solving
 GCS: Glasgow Coma Scale
 IRC: internet resource comparison
 SD: standard deviation
 TBI: traumatic brain injury
 TOPS: Teen Online Problem Solving

Characteristics of excluded studies [ordered by study ID]

| Study | Reason for exclusion |
|-------------|--|
| Wilson 2009 | 5 out of 12 participants (aged 8 to 17 years) had developmental problems rather than brain injury; data were not disaggregated |

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

Bangirana 2009

| | |
|---------------|---|
| Methods | Randomised controlled trial |
| Participants | 65 children who had survived cerebral malaria |
| Interventions | <p>The computerised cognitive rehabilitation training package used was Captain's Log software [31] consisting of 35 multilevel brain-training exercises designed to help develop and remediate a wide range of cognitive skills. 15 of the 35 possible brain-training exercises were chosen for this study. The criteria for deciding which exercises to include were: (1) having little or no verbal instructions so that children with poor grasp of English would benefit, and (2) having simple or few movements with the track-ball. Pretesting demonstrated that Ugandan children, who were for the most part unfamiliar with computers, would be more comfortable using a track-ball than mouse, particularly if required movements were not large. The team that decided on these exercises was led by neuropsychologists who had been trained on using Captain's Log (MJB and BG) who reviewed each of the possible training tasks with team members familiar with the children's languages</p> <p>4 exercises were chosen from the 'Attention Skills: Developmental' module:</p> <ul style="list-style-type: none"> • Scanning Reaction/Inhibition (clicking the mouse if the colour of several varying images matches the colour of the screen's border); • Stimulus Reaction Time (the player is required to click the mouse once if the 'target' image appears); • Stimulus Reaction/Fields (the player is required to move the mouse and click it over the 'target' image); • Stimulus Reaction/Inhibition (clicking the mouse if the colour of several random images appearing one at a time matches the colour of the screen's border). <p>4 exercises were chosen from the 'Conceptual/Memory Skills' module:</p> <ul style="list-style-type: none"> • Conceptual (finding the missing part of a sequence from several choices); • Logical Sequences (finding and clicking on targets in the correct sequence); • Size Discrimination (clicking on target objects in order according to size); • Symbolic Display Match (selecting and placing targets in the correct box based on various rules). <p>3 exercises were chosen from 'Visual Motor Skills' module:</p> <ul style="list-style-type: none"> • Visual Categorisation (clicking on object that appears from behind a door according the category rule); • Visual Response Time (watching a grid of targets and clicking on any that change); • Visuospatial Memory (searching for and find matching objects in a grid). <p>4 exercises were chosen from the 'Logic Skills' module:</p> <ul style="list-style-type: none"> • Concept Logic (figuring out the secret rule in a number of images); • Match Logic (deciding whether images match or not); • Picture Logic (clicking on the target among foils); • Sequential Logic (understanding the conceptual rules in respect to the logic of number/letter patterns). <p>Captain's Log was programmed to run for 45 minutes with the first training session starting at the simplest level and the difficulty increased based on the child's performance</p> |
| Outcomes | The computerised neuropsychological battery Cogstate; Child Behavior Checklist; Middle Childhood Home Observation for Measurement of the Environment Inventory |
| Notes | |

| | |
|---------------|---|
| Methods | Randomised controlled trial |
| Participants | 61 children aged 5 to 12 years with severe malaria |
| Interventions | <p>Captain's Log software [32] consisting of 35 multilevel brain-training exercises designed to help develop and remediate a wide range of cognitive skills. 15 of the 35 possible brain-training exercises were chosen for this study. The criteria for deciding which exercises to include were: (1) having little or no verbal instructions so that children with poor grasp of English would benefit, and (2) having simple or few movements with the track-ball. Pretesting demonstrated that Ugandan children, who were for the most part unfamiliar with computers, would be more comfortable using a track-ball than a mouse, particularly if required movements were not large</p> <p>The computerised cognitive rehabilitation training package used was Captain's Log software [31] consisting of 35 multilevel brain-training exercises designed to help develop and remediate a wide range of cognitive skills. 15 of the 35 possible brain-training exercises were chosen for this study. The criteria for deciding which exercises to include were: (1) having little or no verbal instructions so that children with poor grasp of English would benefit, and (2) having simple or few movements with the track-ball. Pretesting demonstrated that Ugandan children, who were for the most part unfamiliar with computers, would be more comfortable using a track-ball than mouse, particularly if required movements were not large. The team that decided on these exercises was led by neuropsychologists who had been trained on using Captain's Log (MJB and BG) who reviewed each of the possible training tasks with team members familiar with the children's languages</p> <p>4 exercises were chosen from the 'Attention Skills: Developmental' module:</p> <ul style="list-style-type: none"> ● Scanning Reaction/Inhibition (clicking the mouse if the colour of several varying images matches the colour of the screen's border); ● Stimulus Reaction Time (the player is required to click the mouse once if the 'target' image appears); ● Stimulus Reaction/Fields (the player is required to move the mouse and click it over the 'target' image); ● Stimulus Reaction/Inhibition (clicking the mouse if the colour of several random images appearing one at a time matches the colour of the screen's border). <p>4 exercises were chosen from the 'Conceptual/Memory Skills' module:</p> <ul style="list-style-type: none"> ● Conceptual (finding the missing part of a sequence from several choices); ● Logical Sequences (finding and clicking on targets in the correct sequence); ● Size Discrimination (clicking on target objects in order according to size); ● Symbolic Display Match (selecting and placing targets in the correct box based on various rules). <p>3 exercises were chosen from 'Visual Motor Skills' module:</p> <ul style="list-style-type: none"> ● Visual Categorisation (clicking on object that appears from behind a door according the category rule); ● Visual Response Time (watching a grid of targets and clicking on any that change); ● Visuospatial Memory (searching for and find matching objects in a grid). <p>4 exercises were chosen from the 'Logic Skills' module:</p> <ul style="list-style-type: none"> ● Concept Logic (figuring out the secret rule in a number of images); ● Match Logic (deciding whether images match or not); ● Picture Logic (clicking on the target among foils); ● Sequential Logic (understanding the conceptual rules in respect to the logic of number/letter patterns). <p>Captain's Log was programmed to run for 45 minutes with the first training session starting at the simplest level and the difficulty increased based on the child's performance. Children performed 2 sessions once a week for 8 weeks. Four exercises were devoted to attention training as it is a commonly observed deficit after severe malaria</p> |
| Outcomes | Kaufman Assessment Battery for Children-Second Edition; Test of Variables of Attention; Child Behavior Checklist; Wide Range Achievement Test-Third Edition; Middle Childhood Home Observation for Measurement of the Environment Inventory |
| Notes | |

Characteristics of ongoing studies [ordered by study ID]

Boyd 2015

| | |
|---------------------|---|
| Trial name or title | Mitii TM ABI: study protocol of a randomised controlled trial of a web-based multi-modal training program for children and adolescents with an acquired brain injury (ABI) |
| Methods | Waitlisted randomised controlled trial |
| Participants | 60 independently ambulant children (aged 8 to 16 years) at least 12 months post-ABI, acquired ≥ 28 days post-full-term birth |
| Interventions | <p>Mitii: Move it to improve it is an internet-based multimodal therapy that combines upper limb training within the context of meaningful physical activity that can be accessed in children's homes. Inherent in this approach is the ability to scaffold visual perception skills and cognitive challenge, both important aspects of activity engagement in a virtual training environment</p> <p>The program is potentially cost-effective, as only 3 centre-based therapists (occupational therapist, physiotherapist, neuropsychologist) are required to provide initial assessment, goal setting, and training for families and participating children. Each therapist is then able to remotely modify the individualised program each week. The current application proposes to test the efficacy of Mitii in a waitlist randomised controlled trial</p> <p>We propose to provide Mitii at an intensity of 30 minutes per day for 6 days per week over 20 weeks (total dose 60 hours). All children will therefore receive the therapy within 12 months of being randomised either to commence Mitii immediately or after 5 months, with retention of effects tested at 40 weeks</p> <p>As current therapy programmes are resource intensive and time consuming, it is important to determine if gains from Mitii are sustained, as this could offer a cost-effective model of care, particularly for rural, remote, and isolated children with acquired brain injuries</p> |
| Outcomes | <p>Primary outcomes: Assessment of Motor and Process Skills (AMPS); lower limb functional strength</p> <p>Secondary outcomes: Body structure and function domain Jebsen Taylor Test of Hand Function (JTTHF); Melbourne Assessment of Unilateral Upper Limb Function (MUUL); Executive functioning assessed by subtests from the Delis-Kaplan Executive Function System (D-KEFS), Test of Everyday Attention For Children, the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV), the Comprehensive Trail Making Test (CTMT) and the Tower of London-Second Edition. Behaviour Rating Inventory of Executive Function (BRIEF) parent report; Conners 3rd EditionTM; Test of Visual Perceptual Skills (TVPS); 6-Minute Walk Test; High-Level Mobility Assessment Tool; The Timed Up and Go (TUG) test; Assisting Hand Assessment (AHA); Habitual Physical Activity (HPA); Canadian Occupational Performance Measure (COPM); MobQues47; Child and Adolescent Scale of Environment (CASE); Child and Adolescent Scale of Participation (CASP); Participation and Environment Measure for Children and Youth (PEM-CY); Strengths and Difficulties Questionnaire (SDQ); KIDSCREEN-52; Child Health Utility; environmental and personal factors; exit interview; healthcare costs</p> <p>Classification measures: Australasian Rehabilitation Outcome Centre (AROC) impairment codes; classification of brain lesion by structural magnetic resonance imaging; classification of brain injury severity by GCS, LOC, or PTA; Gross Motor Function Classification System (GMFCS); Manual Abilities Classification System (MACS); Edinburgh Handedness Inventory; passive range of motion (PROM); sensory measures including stereognosis, moving two-point discrimination, and texture tactile perception; mirror movements; grip strength; anthropometric data; Wechsler Intelligence Scale for Children-Fourth Edition; neurovascular measures (whole-brain fMRI); diffusion imaging acquisition and white matter fibre tracking</p> |
| Starting date | April 2014 |
| Contact information | Emmah Baque (e.baque@uq.edu.au) |

Boyd 2015 (Continued)

| | |
|-------|--|
| Notes | Primary outcome stated with trial registration at (www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=363939) differs from that of the published protocol |
|-------|--|

NCT02305212

| | |
|---------------------|---|
| Trial name or title | Cogmed for working memory after TBI |
| Methods | Randomised controlled trial |
| Participants | People with TBI aged 9 to 59 years |
| Interventions | Cogmed is a cognitive rehabilitation protocol designed to improve working memory. The Cogmed sessions are administered on a home computer for 30 to 40 min per day, 5 days per week for 5 weeks |
| Outcomes | Primary outcome: Change in scores on standardised tests of working memory Secondary outcomes: Change in scores on self reported measures of emotional functioning; change in scores on self reported measures of memory functioning; change in scores on self reported measures of quality of life |
| Starting date | December 2013 |
| Contact information | Julia Coyne (jcoyne@kesslerfoundation.org) and Nancy Moore (nbmoore@kesslerfoundation.org) |
| Notes | |

fMRI: functional magnetic resonance imaging

GCS: Glasgow Coma Scale

LOC: loss of consciousness

PTA: post-traumatic amnesia

TBI: traumatic brain injury

DATA AND ANALYSES

Comparison 1. Technological aid vs internet resource comparison

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|--|----------------|---------------------|---|----------------------|
| 1 Executive functioning (various measures) | 3 | 194 | Std. Mean Difference (IV, Random, 95% CI) | -0.37 [-0.66, -0.09] |
| 2 CBCL Internalising subscale | 2 | 158 | Mean Difference (IV, Random, 95% CI) | -5.59 [-11.46, 0.28] |

Comparison 2. Technological aid vs internet resource comparison: Subgroups

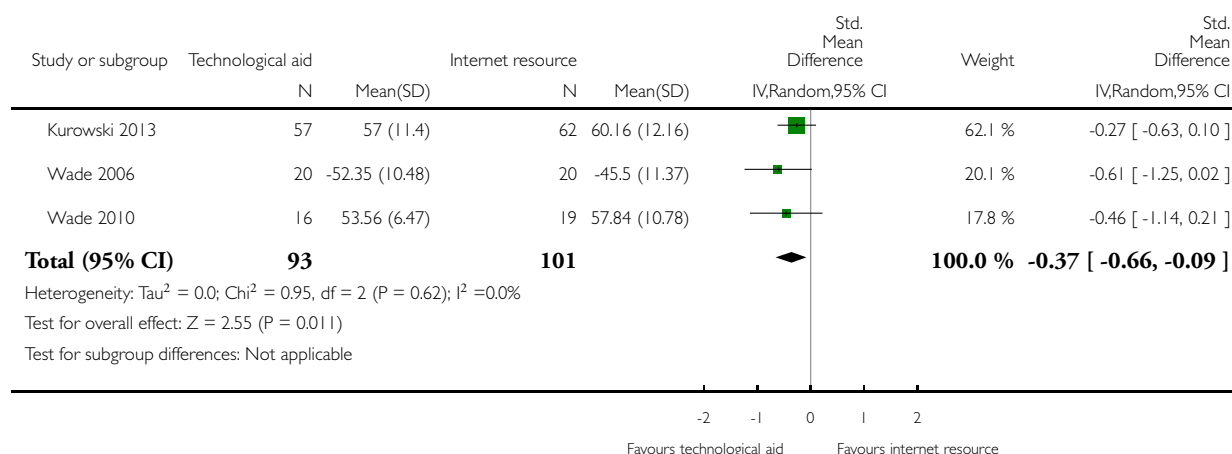
| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|--|----------------|---------------------|---|----------------|
| 1 Executive functioning BRIEF/GEC (moderate) | 1 | | Std. Mean Difference (IV, Random, 95% CI) | Subtotals only |
| 2 Executive functioning BRIEF/GEC (severe) | 1 | | Std. Mean Difference (IV, Random, 95% CI) | Subtotals only |

Analysis 1.1. Comparison 1 Technological aid vs internet resource comparison, Outcome 1 Executive functioning (various measures).

Review: Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury

Comparison: 1 Technological aid vs internet resource comparison

Outcome: 1 Executive functioning (various measures)

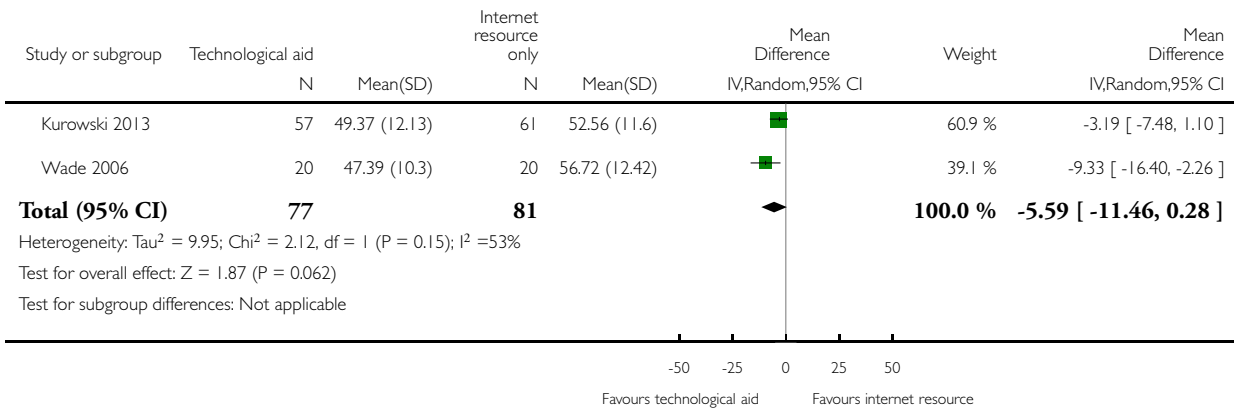


Analysis 1.2. Comparison 1 Technological aid vs internet resource comparison, Outcome 2 CBCL Internalising subscale.

Review: Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury

Comparison: 1 Technological aid vs internet resource comparison

Outcome: 2 CBCL Internalising subscale

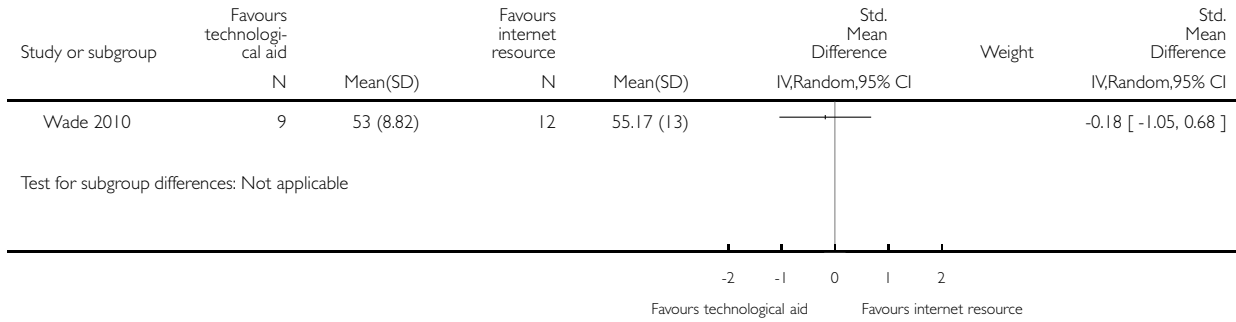


Analysis 2.1. Comparison 2 Technological aid vs internet resource comparison: Subgroups, Outcome 1 Executive functioning BRIEF/GEC (moderate).

Review: Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury

Comparison: 2 Technological aid vs internet resource comparison: Subgroups

Outcome: 1 Executive functioning BRIEF/GEC (moderate)

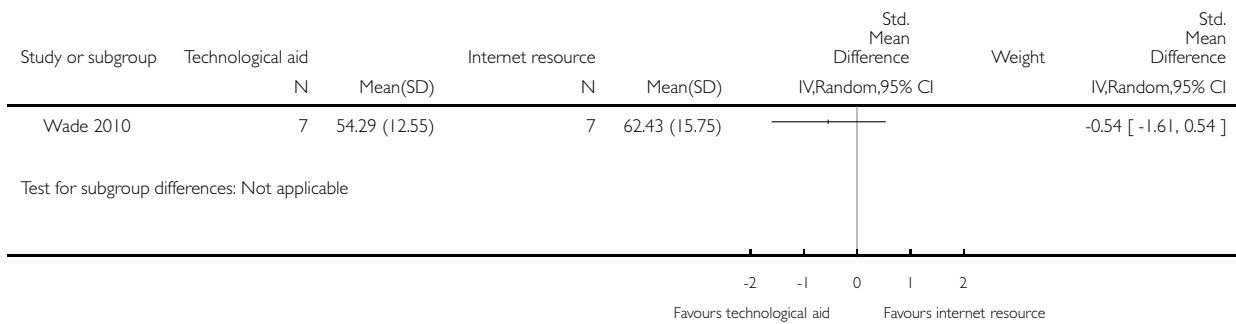


Analysis 2.2. Comparison 2 Technological aid vs internet resource comparison: Subgroups, Outcome 2 Executive functioning BRIEF/GEC (severe).

Review: Technological aids for the rehabilitation of memory and executive functioning in children and adolescents with acquired brain injury

Comparison: 2 Technological aid vs internet resource comparison: Subgroups

Outcome: 2 Executive functioning BRIEF/GEC (severe)



APPENDICES

Appendix I. Search strategies

Cochrane Injuries Group Specialised Register

(((((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) and (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*))) OR (((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) and (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*))) OR (((Glasgow and (coma or outcome) and (scale* or score*)) or “rancho los amigos scale” or (“diffuse axonal injury” or “diffuse axonal injuries”))) OR (((brain or cerebral or intracranial) and (oedema or edema or swell*)) or ((unconscious* or coma* or concuss* or 'persistent vegetative state') and (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)) or (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*))) AND (INREGISTER)REFERENCESTANDARD

Cochrane Central Register of Controlled Trials (CENTRAL)

#1MeSH descriptor: [Craniocerebral Trauma] explode all trees
#2MeSH descriptor: [Brain Edema] explode all trees
#3MeSH descriptor: [Glasgow Coma Scale] explode all trees
#4MeSH descriptor: [Glasgow Outcome Scale] explode all trees
#5MeSH descriptor: [Unconsciousness] explode all trees
#6MeSH descriptor: [Cerebrovascular Trauma] explode all trees
#7MeSH descriptor: [Pneumocephalus] explode all trees
#8MeSH descriptor: [Epilepsy, Post-Traumatic] explode all trees
#9((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) near/3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)):ti,ab,kw (Word variations have been searched)
#10((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) near/3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)):ti,ab,kw (Word variations have been searched)
#11(Glasgow next (coma or outcome) next (scale* or score*)):ti,ab,kw (Word variations have been searched)
#12“rancho los amigos scale”:ti,ab,kw (Word variations have been searched)
#13(“diffuse axonal injury” or “diffuse axonal injuries”):ti,ab,kw (Word variations have been searched)
#14((brain or cerebral or intracranial) near/3 (oedema or edema or swell*)):ti,ab,kw (Word variations have been searched)
#15((unconscious* or coma* or concuss* or 'persistent vegetative state') near/3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)):ti,ab,kw (Word variations have been searched)
#16MeSH descriptor: [Cerebral Hemorrhage] explode all trees
#17MeSH descriptor: [Coma] explode all trees
#18(injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*):ti,ab,kw (Word variations have been searched)
#19#17 and #18
#20MeSH descriptor: [Brain Injuries] this term only
#21#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #19 or #20
#22MeSH descriptor: [Memory Disorders] this term only
#23MeSH descriptor: [Memory] this term only
#24MeSH descriptor: [Cognition] this term only
#25MeSH descriptor: [Executive Function] this term only
#26executive dysfunction:ti,ab,kw (Word variations have been searched)
#27reduced memory:ti,ab,kw (Word variations have been searched)
#28MeSH descriptor: [Cognition Disorders] this term only
#29MeSH descriptor: [Motor Skills] this term only
#30working memory:ti,ab,kw (Word variations have been searched)
#31functionality:ti,ab,kw (Word variations have been searched)
#32“memory*”:ti,ab,kw (Word variations have been searched)
#33((reduced or working) near/1 memory):ti,ab,kw (Word variations have been searched)

#34((executive function* or cognit* or attention or memory) near/3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)):ti,ab,kw (Word variations have been searched)

#35((organiz* or plan* or manag* or “problem solving” or “decision making”) near/3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)):ti,ab,kw (Word variations have been searched)

#36#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35

#37MeSH descriptor: [Rehabilitation] this term only and with qualifier(s): [Methods - MT]

#38rehabilitation:ti,ab,kw (Word variations have been searched)

#39MeSH descriptor: [Reminder Systems] this term only

#40MeSH descriptor: [Self-Help Devices] this term only

#41MeSH descriptor: [Computers] this term only

#42MeSH descriptor: [Computers, Handheld] this term only

#43(external near/3 (aid* or system*)):ti,ab,kw (Word variations have been searched)

#44cognitive aid:ti,ab,kw (Word variations have been searched)

#45(ipad* or tablet* or iphone*):ti,ab,kw (Word variations have been searched)

#46personal data assistant*:ti,ab,kw (Word variations have been searched)

#47“PDA*”:ti,ab,kw (Word variations have been searched)

#48((technical or technological or technology) near/3 (aid* or assist*)):ti,ab,kw (Word variations have been searched)

#49((technical or technological or technology) near/1 (app* or application*)):ti,ab,kw (Word variations have been searched)

#50((memory or electronic or assistive) near/3 (organiser* or device*)):ti,ab,kw (Word variations have been searched)

#51“pager*”:ti,ab,kw (Word variations have been searched)

#52voice recorder*:ti,ab,kw (Word variations have been searched)

#53((answer* or “neuro:page” or paging) near/3 (system* or service* or device*)):ti,ab,kw (Word variations have been searched)

#54((smart or cellular or mobile) near/1 (phone* or telephone*)):ti,ab,kw (Word variations have been searched)

#55#37 or #38 or #39 or #40 or #41 or #42 or #43 or #44 or #45 or #46 or #47 or #48 or #49 or #50 or #51 or #52 or #53 or #54
#56#21 and #36 and #55

Ovid MEDLINE(R), Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid OLDMEDLINE(R)

1. exp Craniocerebral Trauma/
2. exp Brain Edema/
3. exp Glasgow Coma Scale/
4. exp Glasgow Outcome Scale/
5. exp Unconsciousness/
6. exp Cerebrovascular Trauma/
7. exp Pneumocephalus/
8. exp Epilepsy, post traumatic/
9. ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)):ab,ti.
10. ((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)):ti,ab.
11. (Glasgow adj (coma or outcome) adj (scale* or score*)):ab,ti.
12. “rancho los amigos scale”.ti,ab.
13. (“diffuse axonal injury” or “diffuse axonal injuries”).ti,ab.
14. ((brain or cerebral or intracranial) adj3 (oedema or edema or swell*)):ab,ti.
15. ((unconscious* or coma* or concuss* or ‘persistent vegetative state’) adj3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)):ti,ab.
16. exp Cerebral Hemorrhage/
17. exp coma/
18. (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*):ti,ab.
19. 17 and 18
20. Brain Injuries/
21. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 19 or 20

22. Memory Disorders/
23. Memory/
24. cognition/ or executive function/
25. executive dysfunction.mp.
26. reduced memory.mp.
27. Cognition Disorders/
28. Motor Skills/
29. working memory.mp.
30. functionality.mp.
31. "memory*".ab,ti.
32. ((reduced or working) adj1 memory).ab,ti.
33. ((executive function* or cognit* or attention or memory) adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.
34. ((organiz* or plan* or manag* or "problem solving" or "decision making") adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.
35. 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34
36. 21 and 35
37. Rehabilitation/mt [Methods]
38. rehabilitation.fs.
39. Reminder Systems/
40. Self-Help Devices/
41. Computers/
42. Computers, Handheld/
43. (external adj3 (aid* or system*)).ab,ti.
44. cognitive aid.mp.
45. (ipad* or tablet* or iphone*).ab,ti.
46. personal data assistant*.mp.
47. "PDA*".ab,ti.
48. ((technical or technological or technology) adj3 (aid* or assist*)).ab,ti.
49. ((technical or technological or technology) adj1 (app* or application*)).ab,ti.
50. ((memory or electronic or assitive) adj3 (organiser* or device*)).ab,ti.
51. "pager*".ab,ti.
52. voice recorder*.ab,ti.
53. ((answer* or "neuro:page" or paging) adj3 (system* or service* or device*)).ab,ti.
54. ((smart or cellular or mobile) adj1 (phone* or telephone*)).ab,ti.
55. 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 53 or 54
56. 36 and 55
57. randomi?ed.ab,ti.
58. randomized controlled trial.pt.
59. controlled clinical trial.pt.
60. placebo.ab.
61. clinical trials as topic.sh.
62. randomly.ab.
63. trial.ti.
64. Comparative Study/
65. 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64
66. (animals not (humans and animals)).sh.
67. 65 not 66
68. 56 and 67

EMBASE Classic + EMBASE (OvidSP)

1. exp Craniocerebral Trauma/
2. exp Brain Edema/
3. exp Glasgow Coma Scale/

4. exp Glasgow Outcome Scale/
5. exp Unconsciousness/
6. exp Cerebrovascular Trauma/
7. exp Pneumocephalus/
8. exp Epilepsy, post traumatic/
9. ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)).ab,ti.
10. ((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)).ti,ab.
11. (Glasgow adj (coma or outcome) adj (scale* or score*)).ab,ti.
12. "rancho los amigos scale".ti,ab.
13. ("diffuse axonal injury" or "diffuse axonal injuries").ti,ab.
14. ((brain or cerebral or intracranial) adj3 (oedema or edema or swell*)).ab,ti.
15. ((unconscious* or coma* or concuss* or 'persistent vegetative state') adj3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)).ti,ab.
16. exp Cerebral Hemorrhage/
17. exp coma/
18. (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*).ti,ab.
19. 17 and 18
20. Brain Injuries/
21. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 19 or 20
22. Memory Disorders/
23. Memory/
24. cognition/ or executive function/
25. executive dysfunction.mp.
26. reduced memory.mp.
27. Cognition Disorders/
28. Motor Skills/
29. working memory.mp.
30. functionality.mp.
31. "memory*".ab,ti.
32. ((reduced or working) adj1 memory).ab,ti.
33. ((executive function* or cognit* or attent* or memory) adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.
34. ((organiz* or plan* or manag* or "problem solving" or "decision making") adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.
35. 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34
36. 21 and 35
37. Rehabilitation/mt [Methods]
38. rehabilitation.fs.
39. Reminder Systems/
40. Self-Help Devices/
41. Computers/
42. Computers, Handheld/
43. (external adj3 (aid* or system*)).ab,ti.
44. cognitive aid.mp.
45. (ipad* or tablet* or iphone*).ab,ti.
46. personal data assistant*.mp.
47. "PDA*".ab,ti.
48. ((technical or technological or technology) adj3 (aid* or assist*)).ab,ti.
49. ((technical or technological or technology) adj1 (app* or application*)).ab,ti.

50. ((memory or electronic or assitive) adj3 (organiser* or device*)).ab,ti.
51. "pager*".ab,ti.
52. voice recorder*.ab,ti.
53. ((answer* or "neuro?page" or paging) adj3 (system* or service* or device*)).ab,ti.
54. ((smart or cellular or mobile) adj1 (phone* or telephone*)).ab,ti.
55. 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 53 or 54
56. 36 and 55
57. exp Randomized Controlled Trial/
58. exp controlled clinical trial/
59. exp controlled study/
60. comparative study/
61. randomi?ed.ab,ti.
62. placebo.ab.
63. *Clinical Trial/
64. exp major clinical study/
65. randomly.ab.
66. (trial or study).ti.
67. 57 or 58 or 59 or 61 or 62 or 63 or 64 or 65 or 66
68. 56 and 67

PsycINFO (OvidSP)

1. exp Traumatic Brain Injury/
2. Head Injuries/
3. Brain Damage/
4. ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)).ab,ti.
5. ((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) adj3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)).ti,ab.
6. (Glasgow adj (coma or outcome) adj (scale* or score*)).ab,ti.
7. "rancho los amigos scale".ti,ab.
8. ("diffuse axonal injury" or "diffuse axonal injuries").ti,ab.
9. ((brain or cerebral or intracranial) adj3 (oedema or edema or swell*)).ab,ti.
10. ((unconscious* or coma* or concuss* or 'persistent vegetative state') adj3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)).ti,ab.
11. exp Cerebral Hemorrhage/
12. exp coma/
13. (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*).ti,ab.
14. 12 and 13
15. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 14
16. Memory Disorders/
17. Memory/
18. cognition/ or executive function/
19. executive dysfunction.mp.
20. reduced memory.mp.
21. Cognitive Impairment/
22. Motor Skills/
23. working memory.mp.
24. functionality.mp.
25. "memory*".ab,ti.
26. ((reduced or working) adj1 memory).ab,ti.
27. ((executive function* or cognit* or attention or memory) adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.

28. ((organiz* or plan* or manag* or “problem solving” or “decision making”) adj3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)).ab,ti.
29. 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28
30. 15 and 29
31. Rehabilitation/
32. rehabilitation.fs.
33. Reminder Systems/
34. Self-Help Devices/
35. Computers/
36. Computers, Handheld/
37. (external adj3 (aid* or system*)).ab,ti.
38. cognitive aid.mp.
39. (ipad* or tablet* or iphone*).ab,ti.
40. personal data assistant*.mp.
41. “PDA*”).ab,ti.
42. ((technical or technological or technology) adj3 (aid* or assist*)).ab,ti.
43. ((technical or technological or technology) adj1 (app* or application*)).ab,ti.
44. ((memory or electronic or assitive) adj3 (organiser* or device*)).ab,ti.
45. “pager*”).ab,ti.
46. voice recorder*.ab,ti.
47. ((answer* or “neuro?page” or paging) adj3 (system* or service* or device*)).ab,ti.
48. ((smart or cellular or mobile) adj1 (phone* or telephone*)).ab,ti.
49. 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 47 or 48
50. 30 and 49
51. exp clinical trials/
52. exp placebo/
53. exp treatment effectiveness evaluation/
54. exp mental health program evaluation/
55. exp experimental design/
56. exp prospective studies/
57. clinical trial*.ab,ti.
58. controlled clinical trial.ab,ti.
59. randomi?ed controlled trial.ab,ti.
60. randomi?ed.ab,ti.
61. placebo.ab.
62. randomly.ab.
63. trial.ti.
64. ((singl* or doubl* or trebl* or tripl*) adj3 (blind* or dummy or mask*)).ab,ti.
65. ((crossover or clin* or control* or compar* or evaluat* or prospectiv*) adj3 (trial* or studi* or study)).ab,ti.
66. 51 or 52 or 53 or 54 or 55 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65
67. exp animals/
68. exp human females/
69. exp human males/
70. 68 or 69
71. 67 not (67 and 70)
72. 66 not 71
73. 50 and 72

ISI Web of Science: Science Citation Index-Expanded (SCI-EXPANDED); Social Sciences Citation Index (SSCI); Conference Proceedings Citation Index-Science (CPCI-S); Conference Proceedings Citation Index-Social Sciences & Humanities (CPCI-SSH)

#39#38 AND #32
 #38#37 AND #36
 #37TS=(((human*)))

#36#35 OR #34 OR #33
 #35TS=(((singl* OR doubl* OR trebl* OR tripl*) SAME (blind* OR mask*)))
 #34TS=(((controlled clinical trial OR controlled trial OR clinical trial OR placebo)))
 #33TOPIC: (((randomised OR randomized OR randomly OR random order OR random sequence OR random allocation OR randomly allocated OR at random OR randomized controlled trial)))
 #32#31 AND #17 AND #8
 #31#30 OR #29 OR #28 OR #27 OR #26 OR #25 OR #24 OR #23 OR #22 OR #21 OR #20 OR #19 OR #18
 #30TOPIC: (((smart or cellular or mobile) near/1 (phone* or telephone*)))
 #29TOPIC: (((answer* or "neuro?page" or paging) near/3 (system* or service* or device*)))
 #28TOPIC: (voice recorder*)
 #27TOPIC: ("pager*")
 #26TOPIC: (((memory or electronic or assitive) near/3 (organiser* or device*)))
 #25TOPIC: (((technical or technological or technology) near/1 (app* or application*)))
 #24TOPIC: (((technical or technological or technology) near/3 (aid* or assist*)))
 #23TOPIC: ("PDA*")
 #22TOPIC: ("personal data assistant*")
 #21TOPIC: ((ipad* or tablet* or iphone*))
 #20TOPIC: ("cognitive aid")
 #19TOPIC: ((external near/3 (aid* or system*)))
 #18TOPIC: (rehabilitation)
 #17#16 OR #15 OR #14 OR #13 OR #12 OR #11 OR #10 OR #9
 #16TOPIC: (((organiz* or plan* or manag* or "problem solving" or "decision making") near/3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)))
 #15TOPIC: (((("executive function*" or cognit* or attention or memory) near/3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)))
 #14TOPIC: (((reduced or working) near/1 memory))
 #13TOPIC: ("memory*")
 #12TOPIC: (functionality)
 #11TOPIC: ("working memory")
 #10TOPIC: ("reduced memory")
 #9TOPIC: ("executive dysfunction")
 #8#7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1
 #7TOPIC: (((unconscious* or coma* or concuss* or "persistent vegetative state") near/3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*)))
 #6TOPIC: (((brain or cerebral or intracranial) near/3 (oedema or edema or swell*)))
 #5TOPIC: (((("diffuse axonal injury" or "diffuse axonal injuries"))
 #4TOPIC: ("rancho los amigos scale")
 #3TOPIC: ((Glasgow adj (coma or outcome) next (scale* or score*)))
 #2TOPIC: (((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) near/3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*)))
 #1TOPIC: (((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) near/3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*)))

CINAHL Plus (EBSCO Host)
 S65 S53 AND S64
 S64 S54 or S55 or S56 or S57 or S58 or S59 or S60 or S61 or S62 or S63
 S63 MH quantitative studies
 S62 TX random* N3 allocat*
 S61 (MH "Random Assignment")
 S60 TX placebo*
 S59 (MH "Placebos")
 S58 TX randomi?ed N3 control* N3 trial*
 S57 TI ((singl* N3 blind*) or (doubl* N3 blind*) or (trebl* N3 blind*) or (tripl* N3 blind*)) or TI ((singl* N3 mask*) or

(doubl* N3 mask*) or (trebl* N3 mask*) or (tripl* N3 mask*)) or AB ((singl* N3 blind*) or (doubl* N3 blind*) or (trebl* N3 blind*)) or AB ((singl* N3 mask*) or (doubl* N3 mask*) or (trebl* N3 mask*) or (tripl* N3 mask*))

S56 TX clinical N3 trial*

S55 PT clinical trial*

S54 (MH "Clinical Trials")

S53 S34 AND S52

S52 S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 OR S49 OR S50 OR S51

S51 ((smart or cellular or mobile) N1 (phone* or telephone*))

S50 ((answer* or "neuro?page" or paging) N3 (system* or service* or device*))

S49 voice recorder*

S48 "pager*"

S47 ((memory or electronic or assitive) N3 (organiser* or device*))

S46 ((technical or technological or technology) N1 (app* or application*))

S45 ((technical or technological or technology) N3 (aid* or assist*))

S44 "PDA*"

S43 personal data assistant*

S42 (ipad* or tablet* or iphone*)

S41 cognitive aid

S40 (external N3 (aid* or system*))

S39 (MH "Computers and Computerization") OR (MH "Computers, Hand-Held")

S38 (MH "Assistive Technology Devices")

S37 (MH "Reminder Systems")

S36 rehabilitation

S35 (MH "Rehabilitation/MT")

S34 S19 AND S33

S33 S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32

S32 ((organiz* or plan* or manag* or "problem solving" or "decision making") N3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability))

S31 ((executive function* or cognit* or attention or memory) N3 (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability))

S30 ((reduced or working) N1 memory)

S29 "memory*"

S28 functionality

S27 working memory

S26 (MH "Motor Skills")

S25 (MH "Cognition Disorders")

S24 reduced memory

S23 executive dysfunction

S22 (MH "Cognition")

S21 (MH "Memory")

S20 (MH "Memory Disorders")

S19 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S17 OR S18

S18 (MH "Brain Injuries")

S17 S15 AND S16

S16 (injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*)

S15 (MH "Coma")

S14 (MH "Cerebral Hemorrhage+")

S13 ((unconscious* or coma* or concuss* or 'persistent vegetative state') N3 (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*))

S12 ((brain or cerebral or intracranial) N3 (oedema or edema or swell*))

S11 ("diffuse axonal injury" or "diffuse axonal injuries")

S10 “rancho los amigos scale”
 S9 (Glasgow N1 (coma or outcome) N1 (scale* or score*))
 S8 ((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) N3 (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*))
 S7 ((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) N3 (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*))
 S6 (MH “Epilepsy, Post-Traumatic”)
 S5 (MH “Pneumocephalus”)
 S4 (MH “Unconsciousness+”)
 S3 (MH “Glasgow Coma Scale”)
 S2 (MH “Cerebral Edema+”)
 S1 (MH “Head Injuries+”)

PubMed

Search (((((((((((Rehabilitation) OR Rehabilitation[MeSH Terms])) OR (((Reminder Systems[MeSH Terms]) OR Self-Help Devices[MeSH Terms]) OR Computers[MeSH Terms]) OR Computers, Handheld[MeSH Terms])) OR (((((((external and (aid* or system*)))) OR “cognitive aid”) OR ((ipad* or tablet* or iphone*)) OR “personal data assistant”) OR “PDA*)) OR (((((((technical or technological or technology) and (aid* or assist*))) OR (((technical or technological or technology) and (app* or application*))) OR (((memory or electronic or assistive) and (organiser* or device*))) OR “pager”) OR “voice recorder”) OR (((answer* or “neuro?page” or paging) and (system* or service* or device*))) OR (((smart or cellular or mobile) and (phone* or telephone*))) OR (((((((technical OR technological OR technology) and (aid* OR assist*))) OR (((technical OR technological OR technology) and (app* OR application*))) OR (((memory OR electronic OR assistive) and (organiser* OR device*))) OR “pager”) OR “voice recorder”) OR (((answer* OR “neuro?page” OR paging) and (system* OR service* OR device*))) OR (((smart OR cellular OR mobile) and (phone* OR telephone*)))))) AND (((((((Memory Disorders[MeSH Terms]) OR Memory[MeSH Terms]) OR (Cognition[MeSH Terms]) OR executive function[MeSH Terms])) OR (“executive dysfunction”) OR “reduced memory”) OR ((Cognition Disorders[MeSH Terms]) OR Motor Skills[MeSH Terms])) OR (((((((“working memory”) OR functionality) OR “memory*”) OR (((reduced or working) and (memory)))) OR (((executive function* or cognit* or attention or memory) and (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)))) OR (((organiz* or plan* or manag* or “problem solving” or “decision making”) and (disorder* or dysfunction or impaired or impairment or difficult* or problem* or disability)))) AND (((((((((((Craniocerebral Trauma[MeSH Terms]) OR Brain Edema[MeSH Terms]) OR Glasgow Coma Scale[MeSH Terms]) OR Glasgow Outcome Scale[MeSH Terms]) OR Unconsciousness[MeSH Terms]) OR Cerebrovascular Trauma[MeSH Terms]) OR Pneumocephalus[MeSH Terms]) OR Epilepsy, post traumatic[MeSH Terms])) OR (((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra?cran* or inter?cran* or intracran* or intercran*) and (injur* or trauma* or damag* or lesion* or wound* or destruction* or oedema* or edema* or contusion* or concus* or fracture*))) OR (((head or crani* or cerebr* or brain* or intra?cran* or inter?cran* or intracran* or intercran*) and (haematoma* or hematoma* or haemorrhag* or hemorrhag* or bleed* or pressur*))) OR (((((((Glasgow and (coma or outcome) and (scale* or score*))) OR “rancho los amigos scale”) OR (“diffuse axonal injury” or “diffuse axonal injuries”)) OR (((brain or cerebral or intracranial) and (oedema or edema or swell*))) OR (((unconscious* or coma* or concuss* or ‘persistent vegetative state’) and (injur* or trauma* or damag* or wound* or fracture* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur*))) OR Cerebral Hemorrhage[MeSH Terms]) OR ((coma[MeSH Terms]) AND (((injur* or trauma* or damag* or wound* or fractur* or contusion* or haematoma* or hematoma* or haemorrhag* or hemorrhag* or pressur* or lesion* or destruction* or oedema* or edema* or contusion* or concus*))) OR Brain Injuries[MeSH Terms])) AND (((((((randomized controlled trial[Publication Type]) OR controlled clinical trial[Publication Type]) OR randomized [tiab]) OR placebo [tiab]) OR drug therapy [sh]) OR randomly [tiab]) OR trial [tiab]) OR groups [tiab])) NOT ((animals [mh] NOT humans [mh])) NOT medline[sb]

ClinicalTrials.gov

INFLECT EXACT “Interventional” [STUDY-TYPES] AND (brain AND injury) [DISEASE] AND (aid OR aids OR technological OR computer OR device OR electronic OR reminder) [TREATMENT]

WHO International Clinical Trials Registry Platform

Condition: brain injury

AND

Intervention: computer OR device OR reminder OR aid OR aids OR technological OR electronic

AND

Recruiting: ALL

CONTRIBUTIONS OF AUTHORS

All authors contributed to the review.

ML led the review and drafted the manuscript with all other authors approving the final version.

DECLARATIONS OF INTEREST

ML: None known.

CH: None known.

BB: None known.

JE: Professor Jonathan Evans has received research grants and published scientific papers relevant to the subject of this review. He has not received any fees for any aspect of the preparation of this review.

VA: None known.

COR: None known.

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- Research and Development Office Northern Ireland, and Health Research Board, Ireland. Fellowship awarded to Mark A Linden

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

COR conducted the data extraction in place of CH. COR has been added as an author.

We incorrectly referred to the 'Children's Cooking Task' as the 'Chocolate Cake Task'.

We altered secondary outcome measures from 'dichotomous' to 'continuous' data to better reflect how these would be reported in the literature.

We decided to include cross-over and cluster-randomised trials; however, none were identified that met the inclusion criteria.

In response to peer review we have removed the sentence "This review will focus on aids which are used as a compensatory approach" and have added additional information to the Description of the intervention section to emphasise our inclusion of restorative approaches.

We added a 'Summary of findings' table to the review to be in line with current best practice.