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Memory outcomes following cognitive interventions in children with neurological deficits: A review with a focus on under-studied populations

Yael Schaffer and Ronny Geva

Department of Psychology, The Gonda Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat Gan, Israel

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Given the primary role of memory in children's learning and well-being, the aim of this review was to examine the outcomes of memory remediation interventions in children with neurological deficits as a function of the affected memory system and intervention method. Fifty-seven studies that evaluated the outcome of memory interventions in children were identified. Thirty-four studies met the inclusion criteria, and were included in a systematic review. Diverse rehabilitation methods for improving explicit and implicit memory in children were reviewed. The analysis indicates that teaching restoration strategies may improve, and result in the generalisation of, semantic memory and working memory performance in children older than 7 years with mild to moderate memory deficits. Factors such as longer protocols, emotional support, and personal feedback contribute to intervention efficacy. In addition, the use of compensation aids seems to be highly effective in prospective memory tasks. Finally, the review unveiled a lack of studies with young children and the absence of group interventions. These findings point to the importance of future evidence-based intervention protocols in these areas.

Keywords: Paediatric; Rehabilitation; Memory; Restoration; Compensation.

Correspondence should be addressed to Prof. Ronny Geva, Department of Psychology, Head of the Developmental Neuropsychology Lab, The Gonda Brain Research Center, Bar-Ilan University, Ramat Gan, 5290002, Israel. E-mail: ronny.geva@biu.ac.il

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INTRODUCTION

Memory, the acquisition, retention and retrieval of information (Squire, 1992), is vital for daily functioning (Squire & Schacter, 2002), yet it is commonly affected by several different childhood central nervous system (CNS) disorders. These include genetically-based malformations, such as trisomy 21 (Conners, 2003; Jarrold, Baddeley, & Phillips, 1999; Jarrold, Purser, & Brock, 2012); acquired brain injury (ABI), such as traumatic brain injury (TBI) (Donders, 2007; Ewing-Cobbs, Fletcher, Levin, Iovino, & Miner, 1998; Souza, Braga, Filho, & Dellatolas, 2007), stroke (Kolk, Ennok, Laugesaar, Kaldoja, & Talvik, 2011) and brain tumours (Mulhern & Butler, 2004; Reeves et al., 2006); as well as various neurodevelopmental disorders, such as fetal alcohol syndrome (Mattson & Riley, 2006; Rasmussen, 2006), and human immunodeficiency virus (HIV) (Smith, Adnams, & Eley, 2008).

Memory is a multi-system construct (Sohlberg & Mateer, 2001). These childhood disorders affect memory functions in different ways as a function of the specific memory system that was affected (Manji, Pei, Loomes, & Rasmussen, 2009; Serra-Grabulosa et al., 2005; Ward, Shum, Wallace, & Boon, 2002). This review is based on a theoretical framework that differentiates between two major components of remembering: explicit and implicit memory systems, which typically refer to remembering past experiences (Schacter & Tulving, 1994); and a prospective memory system, which enables remembering to act in the future (Baddeley, 1997).

Explicit memory

Explicit or declarative memory refers to memories that can be consciously recalled (Baddeley & Hitch, 1994; Tulving, 1972; Willingham, Nissen, & Bullemer, 1989). Schacter and Tulving (1994) differentiate between three types of explicit memory: working memory (WM) (Baddeley, 2000; Baddeley & Hitch, 1994), semantic memory (SM) (Schacter & Tulving, 1994; Wilson & Glisky, 2009) and episodic memory (EM) (Tulving, 1972; Wilson & Glisky, 2009). Childhood CNS disorders often result in impairments in all three (Bangirana et al., 2009; Gorman, Barnes, Swank, Prasad, & Ewing-Cobbs, 2012; Jarrold et al., 2012; Kodituwakku, 2009; Mulhern & Butler, 2004, 2006; Pauly-Takacs, 2012; Serra-Grabulosa et al., 2005; Vargha-Khadem et al., 1997).

Implicit memory

The explicit memory system is complemented by the implicit memory system. Implicit memory is a non-declarative memory system that allows one to learn without conscious awareness, and it is composed of four memory types: priming, simple classical conditioning, non-associative learning and procedural memory (Schacter, 1987; Sohlberg & Mateer, 2001; Tulving, 1972; Tulving & Schacter, 1990). During the last decade many studies have demonstrated preserved implicit memory after acquired brain injury (ABI) in adults and paediatric populations (Vakil, 2005; Ward et al., 2002; Yeates & Enrile, 2005).

Prospective memory

The last memory component relevant for this review is prospective memory (PM). PM is the realisation of a delayed intention, and is commonly defined as remembering to perform an intended action in the future (Baddeley, 1997; Herrmann, Brubaker, Yoder, Sheets, & Tio, 1999; McDaniel & Einstein, 2007). Several CNS disorders, such as TBI, negatively affect PM in children (McCauley & Levin, 2004; Ward, Shum, McKinlay, Baker, & Wallace, 2007), thus rehabilitation for this type of memory seems warranted (McCauley & Pedroza, 2010).

This review explores studies that focus on implicit, explicit and PM improvement in children. As previously demonstrated, research shows consistently that memory deficits in one or more of these systems is a frequent consequence of childhood CNS disorders, and indicates that memory deficits have the potential to impede upon a child's daily functioning in his or her school (Hawley, 2004; Hawley, Ward, Magnay, & Mychalkiw, 2004), community (Van Heugten et al., 2006) and home environment (Kinsella et al., 1995; McCauley & Levin, 2004). In the last decade, cognitive rehabilitation has been frequently recommended for many paediatric patients (Ylvisker et al., 2005), although until recently, research on the effectiveness of memory rehabilitation techniques on paediatric patients with known neurological involvement was scarce (Laatsch et al., 2007; Limond & Leeke, 2005; Michaud, Rivara, Grady, & Reay, 1992). In the past eight years, however, four reviews of cognitive interventions in children (Laatsch et al., 2007; Limond & Leeke, 2005; Ross, Dorris, & McMillan, 2011; Tatla, Sauve, Jarus, Virji-Babul, & Holsti, 2014), one meta-analysis (Karch, Albers, Renner, Lichtenauer, & von Kries, 2013) and one review on the applicability of cognitive rehabilitation for children with ABI (Slomine & Locascio, 2009) have been conducted. These studies concentrated on paediatric populations with brain injury and ABI, and included relatively few studies specifically addressing memory deficits as the target for cognitive rehabilitation. In addition to these reviews, one meta-analysis on WM amenability to cognitive rehabilitation was recently conducted. This review mainly concerns children with attention deficit hyperactivity disorder (ADHD) (Melby-Lervåg & Hulme, 2013), but memory improvements in paediatric cohorts with known neuropathological aetiologies who are not primarily ADHD or autistic are markedly under-studied (Melby-Lervåg & Hulme, 2013). Based on the theoretical body of literature concerning memory systems, a systems-based analysis of intervention efficacy for the treatment of discrete memory systems in children with under-studied neurological disorders seems warranted.

Cognitive rehabilitation

Cognitive rehabilitation has been broadly defined as a systematic intervention designed to improve cognitive and/or behavioural difficulties following a pathological process in order to improve daily functioning (Axelrod et al., 2002). This intervention technique typically involves two essential modes: restoration (Sohlberg & Mateer, 2001) and compensation (Cicerone et al., 2000, 2005). Another approach that may support generalisation is behaviour management (van't Hooft & Norberg, 2009).

In the current context, it is important to note that the distinction between compensatory means as differentiated from restorative ones may have a heuristic value, but there may be some overlap and shared effects between the categories. Improved cognitive function, for example, may allow better compensation, and effective compensation may allow for some restoration of the underlying cognitive function. Nevertheless, this classification may potentially advance our understanding of the efficacy of memory rehabilitation (Sohlberg & Mateer, 2001), and therefore we use this classification here for heuristic purposes in order to delineate the efficacy of each intervention type for improving specific memory deficits.

The first mode of rehabilitation, restoration, aims to restore functions that have been lost. Restoration techniques suggest practising internal compensatory strategies in order to reduce a primary memory deficit (Sohlberg & Mateer, 2001). This is based on the idea that memory can be strengthened using memory drills analogous to a "mental muscle". Such strategies include rehearsal techniques (Belmont & Butterfield, 1969), chunking and mnemonics methods (Wilson & Moffat, 1992), and/or computerised brain training activities that aim to improve focused attention and the ability to ignore distractions (Berry, Zanto, Rutman, Clapp, & Gazzaley, 2009). Restoration can be accomplished explicitly by teaching specific strategies or implicitly by employing training.

The second mode of intervention may be a compensatory one that is based on the idea that planning abilities and external cues can be recruited to moderate the primary memory deficit. This is accomplished by offering effective means to circumvent the memory deficit, such as by encouraging the use of a diary, smartphone alerts, etc. (Cicerone et al., 2005, 2011). These external devices may help patients adjust to their memory deficit, and thus compensate for it in order to cope with everyday demands despite the cognitive impairment (Cicerone et al., 2005).

A different compensatory approach aims to build upon preserved functions to support performance. An example of such an approach is errorless learning. This method was proposed by Wilson and colleagues, who found that since amnesic patients were unable to eliminate errors when learning new information and do not remember their learning experiences and the feedback that they receive due to a compromised explicit episodic memory system, they could learn more efficiently if, during learning, they were not required to produce potentially wrong responses (Wilson, Baddeley, Evans, & Shiel, 1994).

In addition to restoration and compensation, an important intervention method is behaviour management. Behaviour management uses operant techniques, such as conditioning or reinforcements (Domjan, 2003; McCauley, McDaniel, Pedroza, Chapman, & Levin, 2009), and social learning principles, such as parent management training (Braga, Da Paz, & Ylvisaker, 2005; Lindahl & Steneby, 2009), emotion-focused coping (Ramsden & Hubbard, 2002) and mediation, i.e., the interactions that parents have with children about their environment that promotes learning (Feuerstein, 1980), to achieve behaviour change. These methods have been thought of as a vital part of promoting learning directly and indirectly (van't Hooft & Norberg, 2009).

Across all intervention types, one of the major goals of memory intervention is generalisation, a process in which a learned strategy is used in response to situations other than the one for which it was practised (McKeough, Lupart, & Marini, 1995; Shadmehr & Moussavi, 2000). Nevertheless, while brain training programmes may improve performance on a specific subset of skills or tasks, the benefits may not generalise to other domains (Rabipour & Raz, 2012). Generalisation may be particularly challenging for patients with memory difficulties. Thus, it was examined in the current study as a function of intervention type.

The last aim of this review was to focus on young populations in order to gain more insight on brain plasticity and the role of age and neural maturation in paediatric rehabilitation. There is a debate focusing on the advantages of brain plasticity in younger ages (Bryck & Fisher, 2012; Kochanek, 2006; Wass, Scerif, & Johnson, 2012) versus the view that development and maturation may have both positive and negative effects on overall outcome (Giza & Prins, 2006). Therefore, the third aim of the analysis was to survey studies that focus on school aged children as well as younger children in order to gain greater insight on how different stages of maturation influence the ability to memorise a skill or a new set of information using different intervention methods (Bauer, DeBoer, & Lukowski, 2007; Carew & Magsamen, 2010; Jolles & Crone, 2012).

Hence, overall, this review's goals were to present available findings on memory rehabilitation outcomes in children with under-studied CNS disorders by classifying the different programmes into three inter-dependent categories: restoration, compensation or behaviour management; to delineate which memory aspects are the most frequently studied in that category; and to explore within each method category which memory system is responsive to the intervention, with age considered as a moderating factor.

METHODS

Literature search procedure

First, we surveyed the literature on paediatric memory rehabilitation by performing computer searches using PsycINFO (1967–2014), MEDLINE (1966–2014), American Psychological Association (APA) PsycNET (1967–2014), PsycBite 1966–2014, and Google Scholar databases. The searches used all possible combinations of the following terms and their synonyms (in English): rehabilitation/remediation/therapy, cognitive/neuro, paediatric/pediatric, child/children/adolescents, memory/recollection/recall, acquired/traumatic brain injury/head injury, and training/treatment/management/intervention. The following search terms, covering all major causes of ABI and neurodevelopmental disorders, were also included: stroke/encephalitis/CNS, infection/oncology/fetal alcohol spectrum disorder/Down syndrome/spina bifida. All citations in all relevant articles were also identified and assessed. In an attempt to focus on the effect of cognitive rehabilitation in children suffering from memory deficits resulting from under-studied CNS disorders, studies focusing on ADHD and/or autism spectrum disorder (ASD) as primary inclusion criteria were not covered in the present review. The reason for this was that both ADHD and ASD are well studied, yet findings from these populations may dilute findings related to markedly under-studied populations who typically also present with attention and socio-communicative issues.

Figure 1 provides a flow diagram of the literature search strategy. The initial search yielded 1824 papers. Inclusion and exclusion criteria were then applied serially. Inclusion criteria were such that: (1) It was an intervention study that addressed memory intervention outcomes; and (2) the mean age of the participants was less than 20 years. Articles were excluded if: (1) The paper was not written in English; (2) the paper did not report original empirical data; (3) the study did not have at least one standardised outcome measure, and (4) the paper reported data on ADHD or ASD cohorts. Based on a review of study titles and these criteria, 1767 studies were excluded. The 57 remaining articles were then screened based on their abstracts using the stated inclusion and exclusion criteria, resulting in the exclusion of 10 more articles. A full article search was then performed on the remaining 47

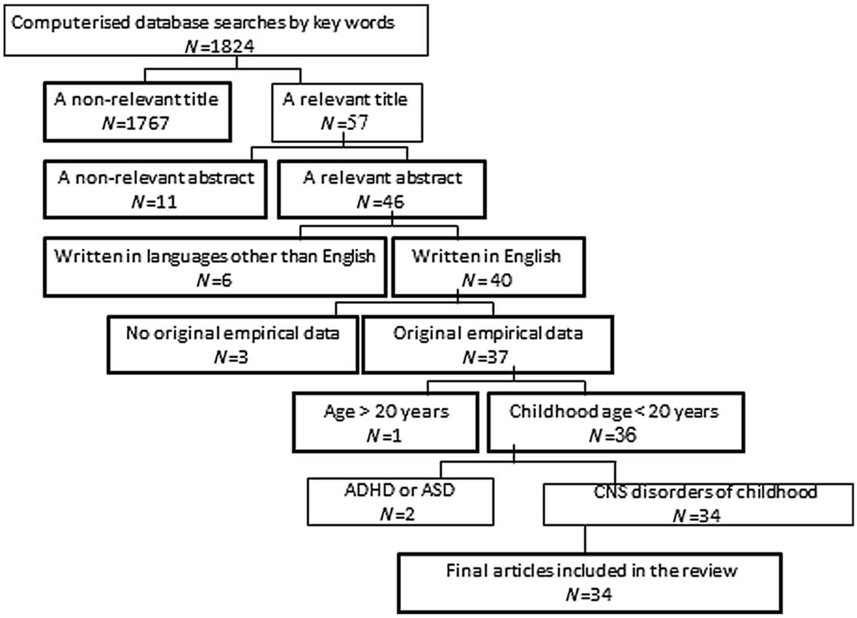

Figure 1. A flow diagram of the papers' review process. ADHD = attention deficit hyperactivity disorder, ASD = autism spectrum disorder, CNS – central nervous system.

studies, and 13 more were excluded for reasons specified in the flow chart (Figure 1). At the end of this process, 34 articles were eligible for the review (detailed in Tables 1 and 2).

Methodological appraisal of included studies

Criteria for the assessment of articles were based on the guidelines of Consolidated Standards of Reporting Trials (CONSORT), with the added guidelines based on Ross and colleagues' (2011) paper (detailed in Appendix 1) resulting in 26 items. Each item was awarded a score of 1 if the criterion was met and 0 if it was not met or it was not possible to determine from the available information. Papers that met 75% of the methodological criteria specified were considered of "high" quality. Papers that were rated between 50 and 75% were deemed of "moderate" quality, and those achieving less than 50% were considered "low" quality. To assess the reliability of this tool, a second reviewer using the same system rated the final 34 papers. Overall percentage agreement was high (90%). Individual disagreement was resolved by discussion with the independent reviewer. This procedure helped address issues concerning the study's specific control conditions, how outcomes were assessed and treatment effect size (Tables 1 and 2).

TABLE 1.
Paediatric memory rehabilitation: Explicit memory methods

Authors	*Year*	*Age*	N	*Type of insult*	*Dur* freq*	*Intervention*	*Memory system*	*Control conditions*	*Effect Size* (r)	*Follow up*	*Outcome assessment*	*Strategy type*	*Experimental Design*	*Quality rating**
Van't Hoolft et al.	2005	9–16	38	ABI	102	AMAT-C	Explicit WM and SM	Children with the ABI at the same age range			ROCFT, digit span, word list	One-to-one comprehensive	Randomised control study	High (76%)
Van't Hoolft et al.	2007	9–17	38	ABI	102	AMAT-C	Explicit WM and SM	Children with the ABI at the same age range		**	15 words list and digit span test	One-to-one comprehensive	Randomised control trial	High (76%)
Van't Hoolft et al.	2009	9–14	3	M	102	AMAT-C	Explicit WM and SM	None. Comparison to baseline performance			ROCFT, RALVT, digit span	One-to-one comprehensive and environmental–familial support	Case study	Moderate (52%)
Van't Hoolft et al.	2003	10–16	3	ABI	120	AMAT-C	Explicit WM and SM	None. Comparison to baseline performance			15 words list and digit span test	One-to-one comprehensive	Case study	Moderate (52%)
Sjo et al.	2010	11–15	7	ABI	100	AMAT-C	Explicit WM and SM	None. Comparison to baseline performance				One-to-one comprehensive	Pre- and post-intervention assessment no control group	Moderate (47%)

(*Continued*)

TABLE 1
Continued

Authors	*Year*	*Age*	N	*Type of insult*	*Dur* freq*	*Intervention*	*Memory system*	*Control conditions*	*Effect Size* (r)	*Follow up*	*Outcome assessment*	*Strategy type*	*Experimental Design*	*Quality rating**
Patel et al.	2009	7–19	12	C	15	Comprehensive programme including	Explicit WM and SM	None. Comparison to baseline performance	.15		CVLT-C	One-to-one comprehensive	Case series	Moderate (41%)
Butler and Copland	2002	6–18	31	C and BT	50	Metacognitive Strategies and clustering skills CRP	Explicit WM and SM	Waiting list, or children who live far from cancer centre	.21		Digit span and sentence memory	Computerised	Control trial	Moderate (70%)
Butler et al.	2008	6–17	161	CM	66	CRP	Explicit WM and SM	Waiting list	.15	**	Digit backward	Computerised	Randomised control trial	Moderate (70%)
											Stroop Color–Word Test Trail Making Test B			
Boivin et al.	2010	6–16	60	HIV	10	CCRT	Explicit WM and SM	Healthy controls	.27		Cogstate computerised neuropsychological test	Computerised	Randomised control trial	Moderate (73%)
Conners	2003	6–14	16	DS	108	Silent rehearsal	Explicit SM	Children with DS practising visual activities	.23		Digit span	One-to-one specific technique	Randomised cross over design	Moderate (64%)
Yerys et al.	2003	11–15	6	SCD	6	Silent rehearsal and semantic organisation	Explicit SM	Children with SCD who received academic tutoring			Digit span, word list, semantic clustering	One-to-one specific technique	Randomised clinical trial	Moderate (47%)

King et al.	2007	8–16	11	SCD	104	Silent rehearsal and semantic clustering	Explicit SM	Children with SCD who received academic tutoring	.53		California Verbal Learning Test	One-to-one specific technique	Randomised control trial	Moderate (50%)
Oberg & Turkustra	1998	18–19	2	TBI	10 and 18	Elaborative encoding	Explicit SM	None. Comparison to baseline performance		**	% of learned word definitions	One-to-one specific technique	Case studies – pre- and post-intervention assessment	Moderate (47%)
Bangirana, et al. Giordan et al.	2009	10 ± 2.6	65	CM	16	CCRT	Explicit WM	Children with CM who received no training sessions	.28		One card learning and one back working memory task from Cogstate test	Computerised	Randomised trial	Moderate (70%)
Bangirana et al.	2011	5–12	61	CM	16	CCRT	Explicit WM	Children with CM who received no training sessions	–.29		Digit span	Computerised	Randomised trial	Moderate (70%)
Hardy et al.	2011	10–17	9	BT	24	CCRT	Explicit WM	None. Comparison to baseline performance	0.21	**	Digit span, letter-number sequencing	Computerised	Pilot with small sample	Moderate (54%)

(*Continued*)

TABLE 1
Continued

Authors	*Year*	*Age*	N	*Type of insult*	*Dur* freq*	*Intervention*	*Memory system*	*Control conditions*	*Effect Size* (r)	*Follow up*	*Outcome assessment*	*Strategy type*	*Experimental Design*	*Quality rating**
Bennet, Holmes, and Buckley	2013	7–12	21	DS	25	JCWMT	Explicit WM and SM	Waiting list	.11	**			Randomised cross over design	High (80%)
Loomes et al.	2008	4–11	33	FASD	4	Silent rehearsal	Explicit WM	Children with FASD who received no training sessions	−.33		Memory Test Battery for Children (WMTB-C)	One-to-one specific technique	Control trial	Moderate (62%)
Rankin and Hood	2005	9–15	2	M	3–9	Mnemonics	Explicit SM	None. Comparison to baseline performance			CMS, ROCFT	One-to-one specific technique	Case study	Low (29%)
Ponsford et al.	2001	6–15	211	TBI	1	Meta-memory Psycho-educational	Explicit WM	Children with minor injuries not involving the head	0		Assessment of memory and learning (WRAML) verbal scale score	Psycho-education	Randomised control trial	Moderate (68%)
Coyne et al.	in press	8–16	15	TBI	1	Retrieval practice	Explicit SM	Items practised with massed restudy, spaced restudy	.66		Number of correct responses across learning conditions	One-to-one	Randomised control trial	Moderate (69%)

TBI = traumatic brain injury; BT = brain tumour; HIV = human immunodeficiency virus; CM = cerebral malaria; ABI = acquired brain injury; SCD = sickle cell disease; M = medulloblastoma; CM = childhood malignancy; FASD - fetal alcohol spectrum disorder; DS = Down syndrome; C = cancer. AMAT-C = Amsterdam Memory and Attention Training for children; CCRT = Captain's Log computerized cognitive rehabilitation therapy; CRP = Cognitive Remediation Program; JCWMT = Junior Cogmed Working Memory Training. WM = working memory; SM = semantic memory; LTM = long-term memory; NR = Not Reported. ROCFT = Rey Osterrieth Complex Figure Test; RALVT = Rey Auditory Learning Verbal Test; CVLT-C = California Verbal Learning Test-Children's version; WMTB-C = Working Memory Test Battery for Children; CMS = Child Memory Scale.

*Adapted from Ross & Dorris (2011), % of 26 quality criterions.

TABLE 2
Pediatric memory rehabilitation: Implicit memory methods

Authors	*year*	*Age*	*N*	*Type of insult*	*Dur* freq*	*Intervention*	*Memory system*	*Control conditions*	*Effect Size (r)*	*Follow up*	*Outcome assessment*	*Strategy type*	*Experimental Design*	*quality rating**
Landis et al.	2006	6–18	34	TBI	14	Errorless learning	Immediate SM	Half of the items were taught the T&E method	−.15	**	Number of correct responses after the study trials	Errorless learning	Retrospective within-subjects concurrent treatment design	Moderate (65%)
Haslam, Bazen-Peters, and Wright	2012	11–16	30	ABI	1	Errorless learning	Immediate SM	15 healthy children	.79		Number of correct responses after the study trials	Errorless learning	Cross over design	Moderate (68%)
Van't Hoolft et al.	2005	9–16	38	ABI	102	AMAT-C	PM	Children with the ABI at the same age range			RBMT	Compensation-comprehensive	Randomised control study	High (76%)
Van't Hoolft et al.	2007	9–17	38	ABI	102	AMAT-C	PM	None. Comparison to baseline performance		**	RBMT	Compensation-comprehensive	Randomised control trial	High (76%)
Van't Hoolft et al.	2003	10–16	3	ABI	120	AMAT-C	PM	None. Comparison to baseline performance			RBMT	Compensation-comprehensive	Case study	Moderate (52%)
Ho et al.	2011	11–17	15	ABI	6		PM	16 healthy control children	.25	**	ROCFT, CMQ and PMQ	Compensation	Case series	Moderate (52%)
Kerns and Thompson	1998	13	1	BT		Individualised memory notebook	PM	None		**	% accomplishing prospective memory tasks	Compensation	Case study – pre- and post-intervention assessment	Low (29%)
Wilson et al.	2009	8–17	12	TBI	7	Memory aids – Neuropage	PM	Waiting list	.97	**	% accomplishing prospective memory tasks	Compensation	Randomised control trial	Moderate (56%)
Gillette and DePompe	2008	6–20	35	TBI	4	PDAs and smartphones	PM	Waiting list versus two PDA groups versus planner			% accomplishing prospective memory tasks	Compensation	Control trial	Moderate (70%)

(*Continued*)

TABLE 2
Continued

Authors	year	Age	N	Type of insult	Dur* freq	Intervention	Memory system	Control conditions	Effect Size (r)	Follow up	Outcome assessment	Strategy type	Experimental Design	quality rating*
McCauley	2009	6–19	84	TBI	2	Monetary incentive	PM	Children with orthopaedic injury	.49		Amount of earned money	Behaviour management	Randomised cross over design	Moderate (64%)
McCauley	2010	6–19	119	TBI	2	Monetary incentive	PM	Children with orthopaedic injury	.59–.44 for moderate TBI, −.12 for severe TBI		Amount of earned money	Behaviour management	Randomised cross over design	Moderate (64%)
McCauley et al.	2011	7–16	115	TBI	2	Monetary incentive	PM	Children with orthopaedic injury	.69 for moderate TBI, .22 for severe TBI	**	Amount of earned money	Behaviour management	Randomised cross over design	Moderate (64%)
Guillery-Girard et al.	2004	11–12	2		5	Errorless learning and vanishing cues	Immediate SM				Number of correct responses after the study trials	Errorless learning	Case study	Moderate (60%)
Martins et al.	2006	7–9.5	2	BT and epilepsy	5	Errorless learning and vanishing cues	Immediate SM	9 healthy controls			Number of correct responses after the study trials	Errorless learning versus vanishing cues	Case study	Moderate (60%)
Pauley-Takacs, Moulin, and Estlin	2012	15	1	BT	2	Errorless learning	Immediate SM	10 healthy controls	0.2	**	Number of correct responses after the study trials	Errorless learning	Case study	Moderate (65%)
Boivin et al.	2013	1.4–5	120	HIV	25	Parents' mediation	Explicit visual SM	60 healthy or HIV dyads who received health and nutrition curriculum	0.5		Color-Object Association Test (COAT) for memory	Behaviour management	Randomised control trial	High (84%)

TBI = traumatic brain injury; BT = brain tumour; HIV = human immunodeficiency virus; ABI = acquired brain injury.
SM = semantic memory; PM = Prospective memory. AMAT-C = Amsterdam Memory and Attention Training for children; PDA = personal digital assistant; RBMT = Rivermead Behavioural Memory Test; ROCFT = Rey Osterrieth Complex Figure Test; CMQ = Child Memory Questionnaire; PMQ = Parent Memory Questionnaire; T & E =trial and error.

* Adapted from Ross & Dorris (2011), % of 26 quality criterions.

Recorded variables and coding

For the purposes of this review, each effect size was coded, along with several important pieces of information describing the population, the memory tasks, the intervention type and the study design.

Four studies employed several memory tasks and/or more than one measure of memory improvement. As a result, these reports included several effect sizes that were incorporated in the analysis wherever appropriate.

Individual effect sizes. We computed effect size using the formula described by Johnson and Eagly (2000), with the provided statistical information in each paper (e.g., means, standard deviations, student *t*-test, *F* test).

Characteristics of the studies

The literature search and inclusion screening yielded 34 articles, quality ratings from a systematic review standpoint (Ross et al., 2011) were conducted according to Standards of Reporting Trials (CONSORT) guidelines (see Appendix 1). Analysis indicated that four studies were considered high quality; 28 were rated as moderate quality and two studies were categorised as low quality. Importantly all included articles were highly commended from a clinical perspective.

Overall, this review included papers with data from 1375 youngsters with memory deficits who participated in intervention studies between the ages of 1.4 and 20 years (M age = 9.8 years, SD = 1.8 years). Most of the memory rehabilitation programmes (28 studies) were planned for and implemented with children older than 6 years. Only three studies (Bangirana et al., 2011; Boivin et al., 2013; Loomes, Rasmussen, Pei, Manji, & Andrew, 2008) included children younger than 6, pointing to a literature gap.

The childhood CNS disorders included in this review are: trisomy 21, acquired brain injury (ABI), traumatic brain injury (TBI), stroke, cerebral malaria, brain tumours, fetal alcohol syndrome and human immunodeficiency virus (HIV).

In most studies ($n = 25$), memory intervention programmes were implemented on a one-on-one basis (teacher, parent, or therapist), while in 10 studies memory intervention programmes were implemented with different computer programmes rather than with a social agent. Intervention in a group setting was not implemented in any of the studies (see Tables 1 and 2), pointing to a literature gap.

Twenty-two studies used various methods in order to improve explicit memory, and 16 investigated methods to improve implicit memory. Three studies used more than one intervention method in their protocol. We will here describe intervention efficacy for each memory system, explicit, implicit and prospective memory systems, as a function of the primary intervention approach.

Explicit memory

Restorative techniques: Inner memory strategies. Restorative techniques for working memory (WM) usually involve chunking and mnemonics methods (Wilson & Glisky, 2009; Wilson & Moffat, 1992). Literature on cognitive rehabilitation of children's WM focuses mainly on two major approaches: a comprehensive strategic approach (one-on-one or computerised) and learning specific strategies (e.g., silent rehearsal or mnemonics). Both intend to promote inner compensation processes.

A comprehensive strategic approach was used in six studies, five of them examined the effect of the Amsterdam Memory and Attention Training for children AMAT-C on children's WM (Sjö, Spellerberg, Weidner, & Kihlgren, 2010; van't Hooft et al., 2005, 2007; van't Hooft, Andersson, Sejersen, Bartfai, & von Wendt, 2003; van't Hooft & Norberg, 2009) and the other examined a different rehabilitation protocol for children older than 7 years of age, teaching problem solving skills and compensatory strategies (Patel, Katz, Richardson, Rimmer, & Kilian, 2009).

All comprehensive protocols included diverse strategies, such as repetition and semantic encoding that relies significantly on the executive component. Regardless of protocol intensity and length, significant improvement in WM was seen, measured by digit span tasks.

Computerised programmes were used in six studies, all with children older than 7 years of age: Two large-scale studies (Butler et al., 2008; Butler & Copland, 2002) tested the Cognitive Remediation Program (CRP) and four studies (Bangirana et al., 2011, 2009; Boivin et al., 2010; Hardy, Willard, & Bonner, 2011) used Captain's Log computerized cognitive rehabilitation therapy (CCRT) (Sandford, 2007). In addition, one study used the Junior Cogmed Working Memory Training (JCWMT) on 21 children aged 7–12 years who had Down syndrome (Bennett, Holmes, & Buckley, 2013). Both CRP and CCRT rely heavily on attention practice as a major part of the intervention, whereas JCWMT mainly consists of WM tasks that are embedded within a game-style environment. In addition, it is important to note that CCRT is not a memory- and attention-specific programme. WM improvement was seen using both longer (more than 12 rehabilitation meetings) and more intense intervention protocols (Bangirana et al., 2009; Butler et al., 2008; Butler & Copland, 2002; Hardy et al., 2011) as well as using shorter protocols, e.g., up to 10 sessions or fewer (Boivin et al., 2010). Finally, earlier intervention, three months post-injury yielded no WM improvement in comparison to later interventions (Bangirana et al., 2011).

In addition to comprehensive and computerised strategic protocols, one study (Loomes et al., 2008) examined the improvement of WM using silent rehearsal among a younger population (children aged 4–11 years). According to this study, children who rehearsed demonstrated WM improvement that was validated using a digit span task. No information was supplied on generalisation in this study.

Six studies examined semantic memory (SM) improvement after a comprehensive memory strategy approach (Patel et al., 2009; Sjö et al., 2010; van't Hooft et al., 2005, 2007, 2003; van't Hooft & Norberg, 2009). Apparently longer and more intense rehabilitation protocols (van't Hooft et al., 2005, 2007, 2003; van't Hooft & Norberg, 2009) yielded more significant improvement in SM in comparison to shorter and less intense rehabilitation protocols (Patel et al., 2009; Sjö et al., 2010). Similar results emerge when testing the efficacy of computerised programmes (CRP and CCRT). Apparently, the use of a short intervention protocol did not improve SM (Boivin et al., 2010) as compared with longer and more intense rehabilitation protocols (4–6 times of practice per week, more than 12 rehabilitation meetings) (Bangirana et al., 2009; Butler et al., 2008; Butler & Copland, 2002; Hardy et al., 2011).

In addition to comprehensive strategic protocols, several studies examined the effect of specific memory strategies, such as silent rehearsal, semantic clustering, retrieval practice and elaborative encoding on SM (Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Coyne, Borg, DeLuca, Glass, & Sumowski, in press; King, White, McKinstry, Noetzel, & DeBaun, 2007; Loomes et al., 2008; Oberg & Turkstra, 1998; Yerys et al., 2003). Overall, specific memory strategies seem to be effective in children. Improvements in simple SM tasks, such as remembering simple words, were seen in all studies (Conners et al., 2008; Coyne et al., in press; Loomes et al., 2008), whereas improvement in more complex SM tasks, such as sentence memory, were seen in longer intervention protocols (King et al., 2007; Oberg & Turkstra, 1998; Yerys et al., 2003).

Errorless learning. Five studies tested the feasibility of errorless learning on SM of children; three of which are case studies. A study of two amnesic children (3 and 6 years at injury; 12 and 11 years of age at test, respectively) (Guillery-Girard, Martins, Parisot-Carbuccia, & Eustache, 2004) found that, although at a slower rate than controls, these children were still able to acquire new concepts using errorless learning approaches, despite profound episodic memory difficulties. Using the same materials and paradigm, Guilerry-Girard and colleagues (2004) reported two further cases of early onset amnesia (6 and 7 years at injury; 9.5 and 7 years of age at test, respectively) with similar findings. However in this case, only the patient with some preservation of episodic memory acquired new concepts at a rate comparable to controls. In the second case study (Martins, Guillery-Girard, Jambaqué, Dulac, & Eustache, 2006) conducted at the same centre, learning was more efficient under errorless conditions for a 15-year-old boy, although access to the information from long-term memory remained cue dependent (Martins et al., 2006).

On a larger scale study, Pauly-Takacs (2012) compared errorless learning with trial-and-error learning of declarative facts in 34 children (aged 6–16 years) with memory disorders secondary to TBI. The results did not support the use of errorless learning as a generalised intervention for learning difficulties that occur after TBI. However, in a recent study, the principle of errorless learning was more effective than trial-and-error learning in helping 15 young people with ABI (Landis et al., 2006). These inconsistent results call for extended research on the effectiveness of incorporating implicit learning techniques, such as use of errorless learning, in memory rehabilitation programmes for children.

Implicit memory

Compensation: External devices. Studies that utilised external memory aids were mainly concerned with PM. A series of studies found promising evidence for diary use in the AMAT-C protocol and in other memory rehabilitation programmes (Patel et al., 2009; van't Hooft et al., 2005, 2007, 2003). These studies demonstrated a major improvement in PM functioning in children aged 9–16 years.

In addition to diaries, the use of electronic devices was also suggested as an effective means for improving PM. For example, Ho et al. (2011) demonstrated the effectiveness of NeuroPage, a paging system in which participants were sent reminder messages regarding the tasks they needed to complete. Other electronic devices, such as personal digital assistance systems, were also found to be effective in another study with a relatively small sample of children and adolescents from a different centre ($N = 12$, 8–17 years) (Wilson et al., 2009). It is important to note that in the long-term, participants demonstrated spontaneous use of the pager to carry out diverse activities and used it freely, pointing to the potential efficacy of use of such a compensatory means in improving PM performance.

Behaviour management. Three studies investigated the influence of behaviour management through reinforcement learning on PM deficits by examining the role of monetary incentives in remediation following paediatric TBI. Results indicated that the high motivation (dollar per point) condition was more effective than the low motivation (penny per point) condition. However, performance of children with severe TBI in the high motivation condition was still significantly lower than controls with orthopaedic injury, and those with mild TBI in both the high and low motivation conditions (DePompei et al., 2008). This suggests that reinforcement may support the efficacy of compensatory means, but it may not necessarily mediate the deficit itself. Another type of behaviour management, conducted through parental mediation, was used in one study and demonstrated promising results on explicit visual memory in young children (aged 1.4–5 years) (McCauley & Pedroza, 2010; McCauley et al., 2009).

In addition, two studies examined how the inclusion of psycho-educational and parental support, either with or without implementing strategies to improve memory performance, supports memory performance in children with CNS disorders. Both studies found that after training/supplying information and coaching, stress levels were lower for both parents and children, and that there was an improvement in explicit WM and SM functioning (Boivin et al., 2013; van't Hooft & Norberg, 2009). This suggests the efficacy of parental support in mediating memory improvement in children with memory deficits.

Generalisation and memory systems. Generalisation of intervention effects is often challenging and is under-studied, limiting the ability to evaluate it. Nevertheless, it was found that short-term generalisation was apparent in seven studies focusing on explicit SM and WM (Butler et al., 2008; King et al., 2007; Oberg & Turkstra, 1998; van't Hooft et al., 2005; van't Hooft et al., 2007; van't Hooft et al., 2003; van't Hooft & Norberg, 2009). This is compatible with the notion that generalisation is one of the attainable goals of memory interventions for paediatric cohorts. Of these studies, five used comprehensive, long and intensive protocols, i.e., more than 12 meetings, usually several times a week (such as in the AMAT-C or CRP interventions programme), indicating, to some extent, near generalisation as well. The effect was especially seen in executive control abilities such as problem-solving skills that were not part of the original targets of the intervention. As for implicit memory, in all of the studies that used compensation aids (e.g., a diary or a smartphone) short-term generalisation was evident (DePompei et al., 2008; Ho et al., 2011; Wilson et al., 2009), such that participants were able to use the reminders in tasks other than the primary task that was tested.

DISCUSSION

Overall, the present review examined the efficacy of memory rehabilitation methods in paediatric cohorts, as a function of the target memory system and rehabilitation method. The review reveals that, especially in the last decade, remedial memory plans for children are used in diverse neurological populations, and in multiple centres around the world and that there is a growing interest in the field of paediatric memory rehabilitation.

The responsiveness of children's discrete memory systems to rehabilitation

The first aim of this review was to investigate the responsiveness of memory systems in children. Findings showed that (1) most of the work in the area focused on WM and SM; (2) the majority of research focuses on children aged 6–17; (3) most of these studies used restoration methods; and (4) some generalisation was noted, mainly for explicit WM and implicit PM. The fact that remedial methods yielded significant improvement, along with the finding that these restorative plans demonstrate some generalisation post-treatment for WM, is consistent with previous findings (Ponsford et al., 2001; van't Hooft & Norberg, 2009) and may resonate with the notion that the WM system benefits more from increased plastic processes during late childhood.

In this context, it is interesting to compare memory system responsiveness in children to that of adults in order to better understand the factors that may promote paediatric memory rehabilitation. In the adult literature, a moderate ability to learn strategies that improve SM is reported to be helpful in real-life contexts outside the treatment context, and near generalisation is seen in patients with mild but not severe memory impairments (Rabipour & Raz, 2012). These findings are somewhat different from the studies exploring paediatric cohorts, in which even children with moderate to severe memory impairments demonstrated memory improvement in response to diverse restoration methods (Bergquist et al., 2009; Glisky & Schacter, 1986; Hampstead et al., 2012; Miller, 1992; Sohlberg & Mateer, 2001). In addition, in many cases with children, near generalisation was also seen. This difference between children and adults is noteworthy, suggesting that brain plasticity may be responsible for this finding in children.

The literature debates the possible benefits of brain plasticity in clinical paediatric populations (Boivin et al., 2010; Butler & Copland, 2002; Conners, 2003; Coyne et al., in press; King et al., 2007; Loomes et al., 2008; Oberg & Turkstra, 1998; Rankin & Hood, 2005). While increased neuroplasticity of the developing brain has generally been thought of as beneficial, it is also known that abnormal neural connectivity can result in impaired functioning and is thought of as "bad plasticity" (Giza & Prins, 2006). Nevertheless, this plasticity debate usually concerns younger children, less than three years old (Wass et al., 2012). A recent review on the effect of laboratory-based training and neurobiologically ecological interventions highlights the importance of conducting school and family-centred prevention interventions in order to improve outcomes for young (4–6 years of age) high-risk children. The authors proposed that the influence of neurobiologically ecological interventions should be explored, especially their impact on executive function neural plasticity (Anderson et al., 2010, 2009; Giza & Prins, 2006; Montour-Proulx et al., 2004; Wass et al., 2012). This notion resonates well with another finding in this review. Indeed, we found that most of the studies examining the outcome of memory rehabilitation were conducted with children older than seven years, with little focus on younger populations. It is not known why there is a literature gap with the younger ages. Such a gap may theoretically arise from more challenges in administering the interventions at younger ages, or may indicate the need to tailor interventions that are better geared to the young, who have immature memory systems and immature executive functions. This direction of thought fits with the finding of a sharp increase in memory performance up to eight years of age, after which performance levels off (Bryck & Fisher, 2012). The use of memory rehabilitation techniques that rely on executive components and focus mainly on WM (Gathercole, 1999; Isaacs & Vargha-Khadem, 2011) after seven years of age may yield better outcomes (Bryck & Fisher, 2012; Rabipour & Raz, 2012). More specifically, it seems plausible to utilise the continued development of top-down enhancement and inhibitory control processes, which are developing in middle childhood, in rehabilitation programmes (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Brocki & Bohlin, 2004). This may highlight the possible mediating roles of executive functions and metacognitive abilities in supporting memory, and may indicate uncertainty regarding whether intervention efficacy is actually due to an improvement in the core memory deficit itself, or whether it is accelerated due to the development of executive functions that occurs at this age. In any event, the mediating roles of executive functions in childhood memory rehabilitation may call for structuring teaching methods to fit appropriately within the individual's functional ability. This may contribute to improvement in explicit memory performance, and brain plasticity may be increased. Future studies with fMRI or DTI that target prefrontal networks may provide further support for this notion.

In addition, an ecological factor may play an important role in the good efficacy after seven years of age. Children at school age have many real-world opportunities to practise memory techniques, especially when learning new materials in school. In contrast, for adults there are typically fewer real-world opportunities to employ the newly learned techniques. For example, most adults with memory-related pathologies are less expected to learn new lists. This suggests that the primary school age range is a target period that may benefit from specific remedial intervention, since "good plasticity" capacity and real-world opportunities are aligned and may interact to improve memory, even in children with severe memory deficits.

In this context it is important to note that lack of evidence related to younger children does not equate to lack of efficacy, but rather may denote a gap in the literature. More research is needed to understand the efficacy of memory rehabilitation programmes on younger children.

The responsiveness of children's discrete memory systems to a specific rehabilitation approach

The second aim was to explore the effectiveness of cognitive rehabilitation techniques for children. Restorative methods employ the teaching of specific memory restoration strategies, often in order to improve explicit SM and WM in children, along with generalisation effects, especially in WM practice. Additionally, the use of comprehensive programmes and a strategy based on diverse memory rehabilitation programmes have shown themselves to be effective. These data support the notion that explicit WM is easier to manipulate and improvements are noted in response to the use of multiple strategies.

More specifically, comprehensive one-on-one strategic memory rehabilitation protocols, such as AMAT-C, seem to produce beneficial effects on explicit SM and WM performance and enable generalisation in children; while use of computerised programmes produce only modest beneficial effects. This discrepancy may be due to several differences between comprehensive one-on-one rehabilitation programmes and computerised programmes. Intervention length is a possible confounding variable that may account for some of the differences between the two intervention types, because the computerised programmes are implemented for less time than the one-on-one restorative programmes (Table 1). This may indicate that restorative methods can become more effective when practised intensively for a prolonged period of time (Sander, Werkle-Bergner, Gerjets, Shing, & Lindenberger, 2012). Other reasons for differences between intervention types are related to the importance of socio-emotional support and reflective processes. The connection between emotional factors and learning was previously documented (Barnes, 1999). In terms of intervention, the child's psychosocial environment possesses necessary stability and resources to support rehabilitation goals (Laukenmann et al., 2003). Although most of the computerised and one-on-one programmes took place in the child's home environment, reflective methods are typically not used in the computerised programmes (Limond, Adlam, & Cormack, 2014). In contrast, the one-on-one programmes also included a weekly meeting with a therapist in a hospital or clinic. The purpose of these meetings is to give feedback and reinforcement, enabling the child to share her/his cognitive, emotional, and behavioural experiences. In so doing, the personal meeting provides emotional support for the child and helps maintain motivation that may, in turn, increase efficacy.

In addition, monitoring the child's progress using reflective methods may help reinforce the generalisation processes in the one-on-one programmes by strengthening meta-memory capacities and supporting internal motivation processes (Bangirana et al., 2011, 2009). This may speak to the importance of treating emotional factors as seriously as memory interventions in rehabilitation programmes because of the major influence that emotional factors have on memory and learning. Indeed, this conclusion has been applied to some comprehensive memory interventions that consider emotional support to be a critical part of the protocol (van't Hooft et al., 2005), as well as in a recent model for paediatric neuro-rehabilitation (Patel et al., 2009; Sjö et al., 2010; van't Hooft et al., 2005, 2007, 2003; van't Hooft & Norberg, 2009). More specifically, Limond and colleagues (2014) recently suggested that the following key clinical areas should be considered in paediatric rehabilitation: pragmatic factors and environmental adaptations, family functioning, challenging behaviour, emotional competence (e.g., a child's ability to recognise emotion, theory of mind), mental health of the child and the family, and motivational factors. These factors provide the foundation for effective paediatric neuro-rehabilitation tests.

In the context of providing emotional support, it seems worth considering reward and the role of behaviour management in memory rehabilitation. The effectiveness of incorporating reinforcements (Limond et al., 2014), psycho-educational support (McCauley et al., 2009; McCauley & Pedroza, 2010) and parental mediation (Ponsford et al., 2001; van't Hooft & Norberg, 2009) on memory deficits in children with CNS disorders was reported in the current review. This underscores the importance of incorporating behaviour management methods, both in the sense of direct intervention (such as reinforcement) or indirect intervention (supporting and focusing on parents), in rehabilitation programmes for children. Furthermore, the study dealing with young children (less than 5 years old) demonstrated that at this age, rehabilitation programmes rely heavily on parental mediation and support (Boivin et al., 2013). Nevertheless, only two studies investigated the efficacy of memory interventions that relied directly on parental support or parent-specific resources (Boivin et al., 2013; van't Hooft & Norberg, 2009). PM, which relies heavily on external monitoring, may benefit from interventions that combine family support with traditional rehabilitation. In addition, given the relationship between negative life events, parental psychological symptoms, and behaviour problems in children with chronic health conditions (Boivin et al., 2013; van't Hooft & Norberg, 2009), research dealing with both direct and indirect effects of family and peer support in the implementation of specific memory interventions (for both PM and explicit memory) is warranted.

In comparison with restorative methods, compensation devices that rely heavily on procedural memory may highlight the supremacy of compensation devices in improving PM. In this analysis, we found that the efficiency of using compensation devices was high even when they were used to treat children with moderate to severe memory deficits. Thus, the incorporation of memory methods that are based on procedural learning may have a beneficial effect in the paediatric population, especially when applied to everyday tasks.

Interestingly, these results are similar to those seen regarding PM improvement in adults. In one adult study, for example, compensation devices were incorporated in PM rehabilitation with promising results (Drotar, 1997; Waaland & Raines, 1991). This similarity may be explained using a developmental perspective. According to Fish et al. (2010) and Reber (1992), PM develops early in life, thus the difference between children and adults is small in their ability to rely on PM when using compensation methods during rehabilitation.

The assimilation of using compensation devices and newly learned strategic methods is partly dependent upon a psycho-education framework and on metacognitive abilities. In this review, we discovered that psycho-education has only been studied directly so far in the context of SM. Nevertheless, the results point to the important role of meta-memory, mediated by authoritative figures and significant carers, in reducing anxiety, optimising early management, and reducing the attribution of pre-existing problems to injury. This may imply that psycho-education is effective because it prevents secondary and tertiary processes by providing plans, real-time support for emotional regulation, and post hoc reflection.

Generalisation

In this context it is important to refer also to early and late generalisation. Comprehensive protocols that incorporated executive function, such as AMAT-C or CRP, demonstrated some late generalisation, especially in regard to executive control abilities such as problem-solving skills.

On the other hand, early generalisation was noted in studies that focused on implicit memory using compensation aids (such as a diary or a Smartphone). This difference raises the question of what conditions contribute to late generalisation. Is it possible that implicit memory interventions result in late generalisation as well? More research is needed to answer these questions.

Under-studied domains and future directions

We noted a lack of studies focusing on group settings of peer or family members in the context of cognitive rehabilitation. All intervention methods included in this review used a one-on-one design, precluding exploration of the therapeutic effect of peer support (Sander et al., 2012). In addition, few studies systematically integrated direct parental support or other behaviour management methods in order to improve efficacy

(Funck-Brentano et al., 2005; Varni, Katz, Colegrove, & Dolgin, 1993). These areas highlight a gap in research that needs to be filled to better understand memory intervention programmes for children suffering from CNS disorders.

Finally, the interaction effects of intervention type, behaviour management method and psycho-education setting may be explored further to better understand the mechanisms involved in intervention efficacy in paediatric cohorts that are neuro-pathologically compromised.

In conclusion, the current literature provides encouraging results, suggesting that interventions effectively alleviate WM, SM and PM difficulties. We found that teaching restoration strategies may improve and result in the generalisation of SM and WM performance in children older than seven years with mild to moderate memory deficits. Further, factors such as long protocols, emotional support, and personal feedback contribute to the efficacy of restoration interventions. In addition, using compensation aids seems to be highly effective in PM tasks.

This review also highlights important under-studied areas in this field, such as the need for exploration of younger participants, group settings, and behaviour management methods. Future studies that fill these gaps may provide important contributions to the evolving field of paediatric rehabilitation and help create the most effective and appropriate guidelines for both service providers and service commissioners.

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APPENDIX 1

Methodological quality appraisals of papers.

Score 1 if met, 0 if not met or unable to determine

(1) Were specific hypotheses and or objectives stated?
(2) Were the settings and locations where data were collected stated?
(3) Was a control or comparison group used?
(4) Were participants randomly allocated to groups?
(5) Is the method of randomisation appropriate?
(6) Was the total sample size $>$ 20 participants?
(7) Was the total sample size $>$ 40 participants?
(8) Were at least some of the measures standardised assessment tools?
(9) Were the measures appropriate for age group?
(10) Were the inclusion exclusion criteria clearly stated?
(11) Did the article specify the severity of the brain injury for participants with acquired brain injury and was the method of diagnosis appropriate (e.g., by a medical professional, Glasgow Coma Scale)?
(12) Did the injury occur at least 6 months previously (to ensure the results were not a reflection of the recovery process)?
(13) Were follow-up data collected after post-intervention data (i.e., to see if effects were maintained post-intervention)?
(14) Were all participants included in the analysis?
(15) If not, was intent-to-treat analysis used? (Award 1 point if a point is granted on the above item.)
(16) Were those assessing the outcomes blind to the group?
(17) Was a power calculation used or sample size justified?
(18) Was the intervention described in detail (i.e., how it was administered, etc.) or was there reference to a manual?
(19) Were the characteristics of participants clearly described (e.g., demographic information such as age, sex)?
(20) Did the results relate to the initial hypotheses?
(21) Was the statistical analysis appropriate?
(22) Were data adequately described (mean, range, etc.)?
(23) Were effect sizes calculated?
(24) Were effect sizes moderate or better (for studies with small sample sizes $n < 10$)?
(25) Was there sufficient information to calculate effect size (i.e. mean and SD)?
(26) Was age taken into account as a possible confounding factor?

Total quality ratings.