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Memory disorders in children

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s0005 THE DIFFERENT MEMORY SYSTEMS

p0005 Memory impairments are observed in a broad range of childhood disorders, either related to direct brain insult (traumatic brain injury, cerebrovascular accident) or to genetic anomalies leading to alterations of brain development. Although different theoretical frameworks of memory functions currently coexist, there is agreement on the existence of at least four different memory systems. Rarely a child will present impairment in all of these systems at the same time. Hence, for efficient diagnosis and treatment, the identification of impaired as well as preserved memory functions is of utmost importance.

p0010 A first memory function is short-term memory (working memory, immediate memory, primary memory) which holds currently perceived or retrieved information in an active and conscious format during the completion of a cognitive task (e.g., maintaining an unfamiliar telephone number one has just looked up in the phone book, for the time needed to dial the number; maintaining a new melody or a new word one has just heard for immediate repetition; maintaining the successive results of an arithmetic problem during mental calculation; maintaining the picture of an unfamiliar object one is copying). Short-term memory allows us to integrate current information with the immediate past and the immediate future and hence is a critical function for maintaining internal thoughts and activated cognitive representations synchronized with ongoing external events. Traditionally, verbal and visuospatial short-term memory subsystems are distinguished although current research suggests that both systems rely on common attentional processes which interact with distinct representational bases (language representations for verbal short-term memory, visuospatial representations for visuospatial short-term memory) (Majerus et al., 2010). A further function of short-term memory is to manipulate and transform currently maintained information (i.e., working memory) and as such is also strongly related to executive functions and attention.

A second system is episodic long-term memory allowing the encoding, storage, and retrieval of information associated with the precise spatiotemporal context in which the information was experienced (e.g., remembering one's last birthday party, remembering the day when one was awarded his/her high school diploma, remembering the holidays spent in Norway last year, remembering the phone call received 10 minutes ago). As such, episodic memory is intimately related to autobiographical memory and the construction of one's identity as an individual with a history of personal events. Episodic memory also has a future-oriented function by enabling us to think of future events (the tasks-to-do today, tomorrow; medical and professional appointments; planned meetings with friends). p0015

Another long-term memory system is semantic memory storing general knowledge, scripts, and facts about the world (e.g., What is a dog? What is a house? What do we do at a restaurant? Which is the capital of Belgium? Why is it cold during winter?). Contrary to episodic long-term memory, no precise contextual information is associated with semantic memories: we simply know that Brussels is the capital of Belgium, even if we do not know where and when we learned this information. Retrieval in semantic memory is usually fast and easy, while it is slower and effortful in episodic memory. Semantic memory is also a contributor to autobiographical memory, by storing self-relevant but decontextualized p0020

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knowledge such as the date one was born, one's nationality, the names of close relatives. Semantic memories are often acquired implicitly, but they can be retrieved explicitly while episodic memories are acquired and retrieved explicitly.

p0025 Finally, procedural long-term memory is a relatively heterogeneous concept broadly regrouping complex sensorimotor knowledge and skills that are acquired implicitly or explicitly and, once fully automatized, are difficult to verbalize (e.g., skilled reading, speaking, writing, advanced music playing, running a cycle, skilled typing on a computer keyboard).

s0010 SHORT-TERM MEMORY DISORDERS

p0030 Impaired short-term memory is reflected by a reduced ability to temporarily store and reproduce verbal and/or visuospatial information that has just been presented. Children with impaired verbal short-term memory will thus show poor ability in the immediate reproduction of verbal sequences (e.g., lists of digits, words or unfamiliar words) and/or visuospatial patterns (e.g., object copying, spatial sequence reproduction). Given the importance of short-term memory as a first step toward long-term learning of new information, these children will typically also have difficulties in learning new verbal information such as a new vocabulary, new definitions, and in learning associations between abstract concepts as for example needed in chemistry (Baddeley et al., 1998). Furthermore given the implication of short-term memory during mental calculation and reasoning, difficulties will also be observed in arithmetic and sentence comprehension. The deficit can be selective for verbal or visual information, or involve both modalities. Although short-term memory deficits do not prevent successful completion of primary and secondary school education, they will nevertheless cause a significant handicap by slowing the affected child's learning rate and his/her comprehension of the explanations and task assignments provided by the teaching staff.

p0035 The observation of a selective short-term memory impairment, in the absence of any other cognitive deficit, is extremely rare. This is partly due to the fact that short-term memory deficits are the consequence of lesions in the inferior parietal lobule and/or the inferior frontal gyrus, most often as a result of a cerebrovascular accident in the territory of the left middle cerebral artery. This kind of accident is rare in children. Furthermore, traumatic brain injury, more common in populations of children, rarely leads to focal and selective lesions in these areas, although short-term memory disorders are a frequent consequence of traumatic brain injury in association with other memory impairments (episodic memory). Three cases have been described presenting a selective verbal short-term memory disorder in the absence of any documented brain insult, but with the predicted accompanying difficulties in learning new verbal information (Baddeley, 1993; Baddeley and Wilson, 1993; Hanten and Martin, 2001). However, at least for two of these cases, more general language impairment could not be completely excluded.

At the same time, short-term memory disorders are p0040
most often observed in association with broader cognitive impairment. Children with specific language impairment and children with dyslexia typically show poor verbal short-term memory and working memory spans; the reduction in verbal short-term memory in these populations cannot be fully explained by their poor language abilities, and hence it is likely that the short-term memory deficits further contribute to the already protracted language development in these children. More generally, verbal short-term memory deficits are a residual deficit in many populations which initially presented more global language impairment patients who presented specific language impairment, childhood aphasia, or epileptic childhood aphasia (Landau-Kleffner syndrome) during childhood can show relatively good language recovery at adulthood but verbal short-term memory impairment will still be present (Majerus et al., 2004).

A number of genetic syndromes are also character- p0045
ized by poor short-term memory spans, either for verbal short-term memory, such as in Down syndrome (trisomy 21) or for visual short-term memory, such as in Williams syndrome (7q11.23) and X-related syndromes (Fragile X, Turner syndrome, Klinefelter syndrome, and Rett syndrome). Velo-cardio-facial syndrome (microdeletion 22q11.21) is particularly interesting here since a specific deficit for the retention of order information has been observed: affected children can accurately maintain and reproduce the items (e.g., words, digits) that have been presented to them but they will have more important difficulties in maintaining and reproducing the order in which the items have been presented (Majerus et al., 2007). Recent studies suggest indeed that one of the major functions of short-term memory is to maintain the order of events that just occurred, the events themselves being directly coded via temporary activation of the respective long-term knowledge bases (i.e., the language system for verbal information) (Majerus, 2009). Finally, we should note that in Fragile X syndrome, the short-term memory impairment is typically more general, including poor retention for verbal, visual, and order information, most likely related to more fundamental attentional difficulties during encoding of information in short-term memory.

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EPISODIC LONG-TERM MEMORY DISORDERS

p0050 Children presenting with episodic memory deficits will have difficulties explicitly learning and/or retrieving new information and its associated spatiotemporal context. These children will forget appointments, tasks-to-do, and activities they had the same day or several days/weeks ago. This will also reduce their ability to project into the future and to design future plans/activities. If there was an acute onset of memory difficulties, memories that have been learned before the onset will generally remain intact and will continue to be retrieved accurately. Furthermore, the deficit can be characterized either by difficulties during encoding (information is not correctly encoded in episodic memory), during consolidation (high forgetting rate), and/or during retrieval (information cannot be retrieved but if correct retrieval cues are provided, performance can be improved). Although these children will show important difficulties in remembering everyday activities, learning of semantic and procedural information via repeated exposure is nevertheless possible. Hence these children can evolve in a standard educational setting in a satisfactory manner, but episodic aspects of learning will be poor or impossible.

p0055 A frequent cause of selective episodic memory deficits, leading to a pattern of developmental amnesia, are lesions to the bilateral hippocampal areas as a result of anoxia, ischemia, or carbon monoxyde poisoning. These lesions will particularly affect the consolidation stage of episodic memory. In some cases, recognition memory can be relatively preserved, as opposed to full, uncued recall. If these lesions occur at a very early age (i.e., at the perinatal stage), the difficulties in episodic memory may be observable only 3 to 4 years later, when episodic memory starts to get recruited more extensively. In some cases, the episodic memory deficit may be restricted to the verbal or the visual condition (Temple and Richardson, 2006).

p0060 Other causes leading to episodic memory deficits are traumatic brain injury (in about 50% of children with traumatic brain injury), brain tumors (especially those involving the third ventricle), and cerebrovascular accidents. Epileptic disorders, especially those involving the medial temporal lobes, are a further frequent cause of episodic memory deficits. If the epileptic foci are unilateral, the memory deficits may be restricted to verbal (left temporal) or visual (right temporal) information, although more general deficits are observed when the foci are bilateral (Temple, 2002). It is important to note that even a single status epilepticus can lead to alterations in the hippocampal regions 5 days after onset (Scott et al., 2002).

More subtle and strategic deficits during memory p0065
retrieval have been observed in children presenting with attention-deficit/hyperactivity disorder (ADHD). Cornoldi and colleagues (1999) observed deficits in 12-year-old children with ADHD in a picture recall task when no information about possible encoding strategies was given (such as regrouping the pictures according to their semantic category). However, recall performance was normalized when the children were informed about the strategy and were trained to use it, indicating that the memory deficits in ADHD are characterized by difficulties in implementing accurate encoding and retrieval strategies, rather than impairment at the level of consolidation. In the same vein, premature birth is a further risk factor for developing episodic memory disorders, although the impairments may be relatively subtle and not significant in all children born preterm.

Finally, episodic memory deficits are also observed in p0070
a range of genetic disorders such as Rett syndrome, Klinefelter syndrome, Down syndrome, velo-cardio-facial syndrome, and Williams syndrome, the two latter syndromes being characterized by an impairment especially for visual episodic memory.

OTHER MEMORY DISORDERS s0020

Semantic memory disorders will lead to deficient factual p0075
knowledge and poor semantic categorization (e.g., Do "cat" and "dog" belong to the same semantic category?), while categorization based on phonological information will be possible (e.g., rhyme judgment). Vocabulary knowledge will also be poor while other language aspects will be preserved. In children, semantic memory disorders are less frequently observed, relative to episodic or short-term memory disorders. They are typically the consequence of lesions to the medial and lateral inferior temporal lobe, even in the absence of damage to the hippocampal area (Temple and Richardson, 2006). Although semantic memory disorders have been less intensively investigated, they appear in children presenting with late-onset temporal lobe epilepsy, especially left mesial temporal lobe epilepsy, although memory impairment is less frequent than it is in adults presenting with the same type of epilepsy (see also Jambaqué & Lassonde, this volume). More generally, impaired semantic memory characterizes a number of genetic syndromes associated with mental retardation, such as Williams syndrome, Down syndrome, and Fragile X.

Finally, difficulties in procedural memory are charac- p0080
terized by various difficulties in learning new sensorimotor skills, such as those involved in becoming a skilled music player, a skilled reader, or a skilled speaker. These difficulties are very rarely observed as a result of acquired brain lesion but may occasionally appear during epileptic

t0005 *Table 27.1*

Synopsis of memory impairments, associated syndromes, and associated cerebral/genetic anomalies

Memory system	Symptoms	Syndromes	Brain lesions/genetic anomaly
Short-term memory			
Verbal	Inability to maintain for a few seconds new verbal information; difficulties in acquiring a new vocabulary	Developmental STM disorder	None
		TBI, CVA , epileptic syndromes	L posterior temporal/L inferior frontal
		Down syndrome	Trisomy 21
		~~Fragile X~~	~~Xq27.3 mutation~~
Order	Difficulties in maintaining the order of events	Velo-cardio-facial syndrome	22q11.2 microdeletion
Visual	Inability to maintain for a few seconds new visual information; difficulties in mental imagery	Traumatic brain injury or CVA	R parieto-occipital
		Williams syndrome	7q11.23 microdeletion
		Fragile X	Xq27.3 mutation
		Turner syndrome	45X0, 47XXX
		Klinefelter syndrome	47XXY, 47XYY, 48XXXY
		Rett syndrome	Xq28 mutation
Episodic memory	Inability to learn new information and its spatiotemporal context; increased forgetting of past and future events	Developmental amnesia	Bilateral hippocampi
		Mesial temporal lobe epilepsy	L and/or R hippocampus
		TBI	Dorso-lateral prefrontal cortex; diffuse axonal injuries
		Brain tumor, CVA	3rd ventricle
		Down syndrome	21 trisomy
		Williams syndrome	7q11.23 microdeletion
		Velo-cardio-facial syndrome	22q11.2 microdeletion
		Klinefelter syndrome	47XXY, 47XYY, 48XXXY
		Rett syndrome	Xq28 mutation
Semantic memory	Inability to learn factual information; poor vocabulary knowledge	Temporal lobe epilepsy	L lateral inferior and medial temporal lobe
		Williams syndrome	7q11.23 microdeletion
Procedural memory	Difficulties to learn sensorimotor skills (speech, reading, music playing, keyboard typing)	Temporal lobe epilepsy	Cerebellar involvement
		Williams syndrome	7q11.23 microdeletion
		Specific language impairment?	None
		Dyslexia?	None

CVA, cerebrovascular accident; STM, short-term memory; TBI, traumatic brain injury; L, left; R, right.

disorders, especially if the cerebellum is involved, as suggested by a study in adult epileptic patients (Hermann et al., 2004). On the other hand, genetic syndromes such as Williams syndrome have been associated with procedural memory disorders, as tested by serial reaction time tasks, possibly related to abnormal development of basal nuclei which are involved in procedural learning. More generally, the difficulties in learning to speak in specific language impairment and in learning to write in dyslexia have been suggested to reflect impairment in procedural memory, preventing the automatization of the complex auditory-motor and visual-motor loops involved in the production of oral and written language, respectively (Ullman and Pierpoint, 2005).

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CONCLUSIONS

p0085 This chapter provides an overview of the main memory disorders encountered in neuropediatric populations (see also Table 27.1). Although we have presented the different disorders as separate entities, some of these can co-occur. For example, lesions to the medial temporal lobe often lead to both semantic and episodic memory deficits, depending on the extent of the lesion and the involvement or not of hippocampal areas. Similarly, impairments in short-term memory and episodic memory frequently co-occur in children suffering from traumatic brain injury. Moreover, the different memory systems interact: although semantic memories can be learned while episodic memory is significantly impaired, a joint intervention of both systems will lead to the fastest learning rate of new information. Similarly, the codes used in short-term memory tasks are shared with long-term memory systems: semantic information in a short-term memory task will be stored by first activating corresponding information in long-term semantic memory. Hence, a deficit in one memory system will also impact on other memory systems. Future studies will need to determine the precise mechanisms that allow these interactions between memory systems and how these interactions can be affected via brain pathology.

References

Baddeley AD (1993). Short-term phonological memory and long-term learning: A single case study. European Journal of Cognitive Psychology 5: 129–148.

Baddeley AD, Wilson BA (1993). A developmental deficit in short-term phonological memory: implications for language and learning. Memory 1: 65–78.

Baddeley AD, Gathercole SE, Papagno C (1998). The phonological loop as a language learning device. Psychol Rev 105: 158–173.

Cornoldi C, Barbieri A, Gaiani C et al. (1999). Strategic memory deficits in attention deficit disorder with hyperactivity participants: the role of executive processes. Dev Neuropsychol 15: 53–71.

Hanten G, Martin RC (2001). A developmental phonological short-term memory deficit: A case study. Brain Cogn 45: 164–188.

Hermann B, Seidenberg M, Sears L et al. (2004). Cerebellar atrophy in temporal lobe epilepsy affects procedural memory. Neurology 63: 2129–2131.

Majerus S (2009). Verbal short-term memory and temporary activation of language representations: the importance of distinguishing item and order information. In: A Thorn, M Page (Eds.), Interactions between short-term and long-term memory in the verbal domain. Psychology Press, Hove, UK, pp. 244–276.

Majerus S, Van der Linden M, Poncelet M et al. (2004). Can phonological and semantic short-term memory be dissociated? Further evidence from Landau-Kleffner Syndrome. Cognitive Neuropsychology 21: 491–512.

Majerus S, Van der Linden M, Braissand V et al. (2007). Verbal short-term memory in children and adults with a chromosome 22q11.2 deletion: a specific deficit in serial order retention capacities? Am J Ment Retard 112: 79–93.

Majerus S, D'Argembeau A, Martinez Perez T et al. (2010). The commonality of neural networks for verbal and visual short-term memory. J Cogn Neurosci 22: 2570–2593.

Scott RC, Gadian DG, King WK et al. (2002). Magnetic resonance imaging findings within 5 days of status epilepticus in childhood. Brain 125: 1951–1999.

Temple C (2002). Developmental amnesias and acquired amnesias of childhood. In: AD Baddeley, MD Kopelman, BA Wilson (Eds.), The Handbook of Memory Disorders. Wiley, Chichester, pp. 521–542.

Temple CM, Richardson P (2006). Developmental amnesia: Fractionation of developing systems. Cognitive Neuropsychology 23: 762–788.

Ullman MT, Pierpoint EI (2005). Specific language impairment is not specific to language: the procedural deficit hypothesis. Cortex 41: 399–433.

Non-Print Items

ABSTRACT

Memory disorders are a frequent consequence of a variety of childhood neurological conditions. We will review the characteristics of memory disorders as a function of the main four memory systems: short-term memory, episodic memory, semantic memory, and procedural memory. For each system, we will identify the most typical cerebral and/or genetic correlates, and we will discuss the impact of impairment of each memory system on everyday life functioning.