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Brief Report

Developmental dissociation between the maturation of procedural memory and declarative memory

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A B S T R A C T

Declarative memory and procedural memory are known to be two fundamentally different kinds of memory that are dissociable in their psychological characteristics and measurement (explicit vs. implicit) and in the neural systems that subserve each kind of memory. Declarative memory abilities are known to improve from childhood through young adulthood, but the developmental maturation of procedural memory is largely unknown. We compared 10-year-old children and young adults on measures of declarative memory and working memory capacity and on four measures of procedural memory that have been strongly dissociated from declarative memory (mirror tracing, rotary pursuit, probabilistic classification, and artificial grammar). Children had lesser declarative memory ability and lesser working memory capacity than adults, but children exhibited learning equivalent to adults on all four measures of procedural memory. Therefore, declarative memory and procedural memory are developmentally dissociable, with procedural memory being adult-like by age 10 years and declarative memory continuing to mature into young adulthood.

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Introduction

Evidence has converged on a fundamental distinction between two forms of memory: declarative and procedural (Cohen & Squire, 1980). Declarative memory ("knowing that") refers to conscious memory for events and facts, is assessed by explicit tests of recall and recognition, and depends on medial temporal lobe and diencephalic brain structures. Procedural memory ("knowing how") refers to unconscious memory, is assessed by experience-dependent learning of skilled performance, and depends on structures in the basal ganglia, cerebellum, and neocortex (Gabrieli, 1998). Declarative memory abilities improve across child and adolescent development (e.g., Kail, 1990), but surprisingly little is known about the development of procedural memory. Here we asked whether procedural memory continues to develop past middle childhood, as does declarative memory, or whether instead procedural memory matures at an earlier age.

There is evidence that some forms of nondeclarative memory mature earlier than declarative memory. Perceptual priming, based on stimulus form, appears to be adult-like early in development (Carroll, Byrne, & Kirsner, 1985; Drummey & Newcombe, 1995). Conceptual priming, based on stimulus meaning, develops more slowly (e.g., Billingsley, Smith, & McAndrews, 2002; Murphy, McKone, & Slee, 2003), perhaps because it relies on the growth of semantic knowledge through development.

Several studies have examined the development of sensorimotor sequence learning. Sequence learning of visuospatial locations appears to mature during infancy when measured by visual saccades (Amso & Davidow, 2012; Lum, Kidd, Davis, & Conti-Ramsden, 2010). Sequence learning for locations can also be measured by reaction times to button presses on the serial reaction time task. Developmental findings using this task have been mixed, with findings of learning in children that is equal to adults (Meulemans, Van der Linden, & Perruchet, 1998; Thomas & Nelson, 2001), less than adults (Thomas et al., 2004), or greater than adults (Janacsek, Fiser, & Nemeth, 2012). The inconsistent developmental findings may relate to factors that influence explicit awareness of the to-be-learned sequence such as the nature of the sequences (Willingham & Goedert-Eschmann, 1999).

Here we examined age differences in learning on four diverse measures of procedural memory selected because they have been dissociated from declarative memory in studies of patients with global amnesia. Therefore, if children exhibit reduced procedural memory relative to adults on these tasks, it is unlikely to be a secondary consequence of immature declarative memory. Two tasks, mirror tracing (Milner, 1962) and rotary pursuit (Corkin, 1968), were the motor skill learning tasks on which the amnesic patient "H.M." and patients with impaired declarative memory due to Alzheimer's disease have shown successful learning (Gabrieli, Corkin, Mickel, & Growdon, 1993; Heindel, Salmon, Shults, Walicke, & Butters, 1989). Despite their landmark status in memory research, neither of these tasks has been used to examine development.

We also examined two cognitive examples of procedural memory. One task was probabilistic classification, which has also revealed intact learning in amnesic patients (Knowlton, Squire, & Gluck, 1994). The other task was artificial grammar learning, the original example of implicit learning (Reber, 1967) and one that has also revealed intact learning in amnesia (Knowlton, Ramus, & Squire, 1992). Artificial grammar learning has been studied in children ages 9 to 11 years (Fischer, 1997) and 5 to 8 years (Witt & Vinter, 2012), but neither study compared learning between children and adults.

Method

Participants

In total, 32 children (mean age = 10.46 years, range = 10.04–10.94; 16 female) and 29 adults (mean age = 23.68 years; 16 female) participated. Of this total sample, 26 children and 27 adults completed all tasks detailed below; some participants were not able to complete all tasks for one or more reasons: ran out of time (children, $n = 5$; adults, $n = 0$); a program crashed (children, $n = 4$; adults, $n = 2$); data were overwritten (children, $n = 1$; adults, $n = 0$) (see Appendix A). Both adults and children received Amazon gift cards for participation ($60) and gave written consent (along with parents of minors).

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