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Development of perceptual and conceptual memory in explicit and implicit memory systems

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A R T I C L E I N F O

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A B S T R A C T

We examined the developmental trajectory of memory while accounting for both memory systems (explicit-implicit) and processing modes (conceptual-perceptual). Four memory tasks that are believed to reflect the four possible combinations of memory systems and processing modes were administered to 96 individuals in three age groups: mid-childhood, mid-adolescence and young-adulthood (mean age 7.7, 13.7 and 21.8, respectively). For perceptual processing, participants performed a Picture Fragment Identification task and a Pictorial Cued Recall task taping the implicit and explicit memory systems, respectively. For conceptual processing, participants performed Category Production and Category Cued Recall tasks taping the implicit and the explicit memory systems, respectively. The study revealed (1) robust maturation effects in the explicit memory system; (2) comparable performance levels for adolescents and adults in all but the explicit-conceptual task; and (3) more pronounced maturation effects for perceptual than for conceptual processing within the implicit memory system.

The idea that memory is not a single faculty of the mind, but rather is comprised of several components, is not a new one. Considerable behavioral and neuroimaging findings point to dissociations between different Memory Systems (explicit vs. implicit) and different Processing Modes (perceptual vs. conceptual), or, alternatively, between different processing components (Cabeza and Moscovitch, 2013). Nevertheless, little is known about the development of these mnemonic components across the human lifespan. As differential maturation rates of cognitive functions can elucidate the nature of functional dissociations, the current study employs a developmental perspective to investigate maturation patterns of different mnemonic components. We sampled the proposed mnemonic space using tasks that represent different combinations of memory components, and tested participants in three age-groups, to evaluate the developmental trajectory of these components.

Memory systems: explicit vs. implicit memory

In past decades, differences in memory performance due to experimental manipulations or brain damage were addressed by distinguishing an explicit memory system from an implicit one. The explicit system can be tapped using recall tasks in which studies information that is not presented at test is retrieved (either freely or following the presentation of a cue), or using recognition tasks in which presented information is classified as either old or new. There is a general consensus that recall tasks require recollection, that is, retrieval of additional contextual details about the encoded event. Recognition, on the other hand, can also be supported by familiarity, that is, a sense of having encountered something or someone before, without retrieval of additional information (e.g., (Yonelinas, 2002)). Notably, both recall and recognition are considered to be explicit (or "declarative") memory tasks, as they both require intentional retrieval.

On the other hand, in tasks like motor skill learning and priming that utilize the implicit system, remembrance can occur incidentally, or without awareness, and memory is inferred by changes in performance such as increased speed and accuracy (Gabrieli, 1998; Schacter, 1990; Squire, 2004). One task that taps the implicit memory system is the Fragment Completion task. In this task, participants view items (e.g., object pictures) during an initial study phase. Next, they view fragments (e.g., degraded versions of object pictures) of studied and unstudied items and are asked to name the items. Facilitation (or priming as indicated by reduced reaction times, for example) is usually observed for correctly identified fragments that were seen before, relative to those that were not previously seen. This facilitation is taken as evidence that retention of the previously encountered items has occurred (e.g., (Cycowicz, 2000)).

Ample evidence supports this distinction between the explicit and implicit memory systems. For example, although amnesic patients are

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severely impaired in their ability to recall or recognize learned stimuli (i.e., explicit memory), they demonstrate robust learning of a variety of skills, and can benefit from various forms of implicit memory, including priming (Brooks and Baddeley, 1976; Cohen et al., 1985; Cohen and Squire, 1980; Shimamura, 1986). Furthermore, patients with damage to the medial temporal lobe (MTL) show impairments in explicit memory and preserved implicit memory, while the opposite pattern of performance is observed in patients with bilateral lesions in the occipital-lobes (Gabrieli et al., 1995; Keane et al., 1995). These findings demonstrate a double dissociation between these memory systems.

Processing modes: conceptual vs. perceptual memory

Another common framework focuses on memory effects that are produced by different types of processing modes. In particular, studies have emphasized the distinction between conceptual and perceptual memory processes (e.g., (Blaxton, 1989; Roediger and McDermott, 1993)). Perceptual memory depends on preliminary stages that analyze physical or sensory features of the stimuli. Conceptual memory, on the other hand, requires higher-level processing and focuses on extraction of meaning and semantic features (Blaxton, 1992; Srinivas and Roediger, 1990). This framework proved highly valuable for accounting for various findings in memory research, including the level of processing effect (Blaxton, 1989; Challis et al., 1996; Challis and Brodbeck, 1992; Craik et al., 1994; Craik and Lockhart, 1972; Srinivas and Roediger, 1990) and divided attention manipulations (e.g., (Insingrini et al., 1995; Vakil and Hoffman, 2004); and see (Mulligan, 1997) for review).

Neuroimaging studies have indicated that perceptual priming is associated with reduced activation in parts of the occipital and inferior temporal brain regions, while conceptual priming is associated with reduced activation in the inferior prefrontal cortex (Cabeza and Nyberg, 2000; Schacter and Buckner, 1998). The notion that these mnemonic processes are distinct was further supported by several studies, in which different groups of patients were examined. For example, in a study by Keane, Gabrieli, Fennema, Growdon, and Corkin (Keane et al., 1991), patients with occipital lesions showed preserved conceptual but not perceptual priming effects. Interestingly, in other studies, patients suffering from closed head injuries (CHI) with damage to the frontal lobes (Bigler and Maxwell, 2012; Levine et al., 2013; Stuss and Gow, 1992; Vakil, 2005), showed the opposite pattern of intact perceptual priming but deficits in conceptual priming (Vakil and Sigal, 1997). More recently, Gong et al. (Gong et al., 2015) demonstrated this double dissociation in a single study: patients with frontal lobe injury showed decreased performance in a conceptual memory task, while patients with damage to the occipital lobe showed decreased performance in a perceptual memory task.

Taken together, previous studies have validated the Memory Systems approach, as well as the Processing Mode approach. However, it is yet to be determined whether these systems and processing modes are orthogonal or if there are any dependencies between them. The current study relies on the assumption that development of mnemonic components depends on maturation of brain regions and the connection pathways that support them. Therefore, the evaluation of these proposed mnemonic components and their interactions can benefit from a developmental perspective.

Developmental perspective

The traditional developmental perspective on memory systems suggested that explicit memory increases with age, reaching maturation relatively late in adolescence or even adulthood (e.g., (Mecklinger et al., 2011; Ofen et al., 2007; Sprondel et al., 2011; Van Strien et al., 2011)), while implicit memory is already developed during early childhood, and does not usually demonstrate a developmental trend (Cycowicz, 2000; Ofen and Shing, 2013; Vöhringer et al., 2017). Nevertheless, some studies have challenged this perspective by demonstrating age-effects in implicit memory tasks as well (Cycowicz et al., 2000; Mecklenbräuker et al., 2003; Vaidya et al., 2007). For example, Cycowicz et al. (Cycowicz et al., 2000) evaluated developmental trends of both implicit and explicit memory in a single study. In their study, participants in 4 age groups (5–7, 9–11, 14–16, and 22–28 years of age) completed a modified version of the picture fragment task. After viewing object pictures, they were asked to identify degraded versions of old and new items, to test their implicit memory. This was followed by a recall task and a recognition task of the same studied items, to test their explicit memory. As expected, performance on the explicit tasks showed improvement with age. Notably, changes were also observed in the implicit task: although facilitation (priming) was significant in all age groups, the amount of priming increased with age. This suggests that even though the implicit memory system is already functional very early on, it continues to develop into adulthood.

Developmental studies on processing modes also show conflicting results. Although some studies do not report any developmental trajectory for perceptual processing (Mecklenbräuker et al., 2003; Perez et al., 1998), other studies challenge these results (e.g., (Cycowicz et al., 2000; Haese and Czernochowski, 2016)). In their recent investigation, Haese and Czernochowski (Haese and Czernochowski, 2016) measured event-related potentials (ERPs) as 7-year-old and 10-year-old children performed an explicit recognition task. Participants studied object pictures and were later asked to discriminate between studied, modified and new pictures. In this case, feature memory (perceptual processing) is indicated by the proportion of correct "identical" responses to identical items, which would require memory of the fine perceptual details (as opposed to memory for the overall "gist"). Although the two groups did not differ in their behavioral performance, robust modulation of the frontal old/new effect (the putative ERP correlate of familiarity-based retrieval) following intentional encoding was observed for identical versus new items in older children, but not in young children. Moreover, modulation of this ERP component for modified versus new items, that is typically observed in young adults (e.g., (Haese and Czernochowski, 2015)), was not observed in either group. This indicates that even when coarse behavioral outcomes do not reveal age-related differences, the underlying neuro-cognitive mechanisms can still shift (e.g., from recollection to familiarity-based recognition) and develop with maturation.

As for conceptual processing, some studies do not show maturation effects for conceptual memory (Anooshian, 1997; Billingsley et al., 2002). For example, in the study by Haese and Czernochowski (Haese and Czernochowski, 2016) described above, the developmental trajectory was only revealed in the second block where items were intentionally encoded, but not in the first block where encoding was incidental. Because the task requirements (i.e., memory for perceptual details) were unknown during the first block, it can be argued that focus has shifted from conceptual processing (in the first block) to perceptual processing (in the second), thus revealing maturation effects that are associated only with the latter. Nevertheless, other studies indicated that developmental effects on conceptual processing do exist. In a recent study that focused on utilization of schemas (cognitive structures that organize conceptual knowledge), Brod, Lindenberger, and Shing (Brod et al., 2016) demonstrated an age-related increase, from childhood to adulthood, in the relative importance of schema-based memory. Additionally, studies have shown a developmental trajectory in tasks that involve conceptual priming (Mecklenbräuker et al., 2003; Murphy et al., 2003; Sauzéon et al., 2012).

Different studies use different samples and different sample characteristics, which can account for some of the discrepancies in the current developmental literature. The number of age groups, as well as their range, vary considerably between studies (e.g., 4 age groups [5–7, 9–11, 14–16, 22–28 years of age] in (Cycowicz et al., 2000); 2 age groups [7–8 and 9–11] in (Haese and Czernochowski, 2016); a group of children [8–10] and a group of young adults [19–27] in (Mecklinger