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Errorful and errorless learning in preschoolers: at what age does the errorful advantage appear?

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ABSTRACT

Explicit memory has been tested extensively in young children. The results show that young children's explicit memory is weak and decays quickly but is in many ways similar to that of adults. However, most studies showed that young children's implicit memory is intact. This inconsistency has lead to a debate about the extent to which the memory of young children resembles that of healthy adults. When adults with impaired explicit memory and intact implicit memory are tested for semantic knowledge, they show better memory under errorless learning procedures. In contrast, healthy adults show better memory under errorful procedures. We tested these two procedures in 3- and 5-year-olds. 3-year-olds remembered less than 5-year-olds, but both groups showed similar errorful learning advantages, which persisted after 5 weeks. Our data show that while 3-year-old children's memory is weak, it is more similar to intact than to impaired explicit memory in adults.

1. Introduction

Memory develops gradually during childhood. For example, Bauer, Doydum et al. (2012) found that 4-year-olds remembered less than 6-year-olds, who in turn remembered less than 8-year-olds. Similar findings have been reported by Perner and Ruffman (1995) and many others (e.g., Pathman, Larkina, Burch & Bauer, 2013; Riggins, Blankenship, Mulligan, Rice, & Redcay, 2015).

It is not clear from what ages memories become permanent. Bauer, Leventon and Varga (2012) argued that children show at a very early age that they can remember events from the past. On the other hand, when adults report their first childhood memory, the average age at the time of their first memory is 3 or 4, and memories from before that age are rare, a phenomena called childhood (or infantile) amnesia. In addition, children have an accelerated rate of forgetting (3 and 4-year-olds more pronounced than 8-year-olds), especially in response to open ended questions (Bauer & Larkina, 2015). It seems that children at the age of 3 do remember past events but this memory contains less information (associations) and is more susceptible to forgetting.

Other populations which show less accurate memory include the elderly and patients with anterograde amnesia. When the memory of elderly and amnesic patients was tested, it was found that memory changes are not just in quantity, but also in quality. Hay and Jacoby (1999) found that whereas elderly people's recollection is impaired, their habit memory is intact. Others have found that explicit memory is more impaired in old age than is implicit memory (Anderson & Craik, 2000). Studies have shown that amnesic patients also have impaired explicit memory, but intact implicit memory (Corkin, 1965; Corkin, 2002).

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The fact that younger children's memory is less accurate does not address the question of whether the differences between adult memory and young children's memory are only in terms of quantity, or also of quality.

Many studies of explicit memory in younger children have focused on episodic memory (the ability to remember an event, the combination of what when and where). For instance, Bauer, Doydum et al. (2012) found that four year old children's ability to remember where events took place was lower than the ability of 8 year old children. Similar findings have been reported for temporal order (Pathman et al., 2013) and activity associated with an item (Riggins et al., 2015). Moreover, it seems that while item memory develops gradually from age 4 to age 10, binding of memory [as shown by fact and source combination] shows accelerated development between the ages of five and seven (Riggins, 2014). Episodic memory, clearly, develops gradually over time.

While it is well established that episodic memory, which is part of explicit memory, develops gradually, most studies find that implicit memory is relatively stable during childhood. For example, Vöhringer et al. (2017) found that implicit memory is stable from 9 months of life to the age of 3 years. Similarly, Finn et al. (2016) tested explicit and implicit memory of 10 year olds and adults and found that children had poorer explicit memory and less working memory capacity than adults, but exhibited learning equivalent to adults on measures of implicit memory. Hayes and Hennessy (1996) found similar findings in 4, 5 and 10 year olds (but see Murphy, McKone & Slee, 2003).

Another aspect of memory, level of processing, shows discontinuity between young children and adults' memory. For example, although level of processing had similar effect for all ages on true memory (Kheirzadeh & Pakzadian, 2016), it had different effects on false memory: Wimmer and Howe (2010) showed that whereas deeper level of processing improved true memory in 4 and 7 year olds and also in adults, it reduced false memory for adults but *increased* false memory for the 7 year olds. As another example, most people remember better in recognition tasks than in free recall tasks. However, this difference is much more pronounced in amnesic (Isaac & Mayes, 1999) and aging people (Perlmutter, 1979). Perner and Ruffman (1995) tested the proportions of correct answers under free recall and recognition conditions in young children. They found that although 4-year-old children were worse than 6-year-old children in memory tasks, this effect was equal for free recall and cued recall. That is, young children did not show more pronounced imbalance between recognition and free recall as did older adults and amnesic patients. Similar results were also found by Cheke and Clayton (2015). Thus, it seems that young children have intact implicit memory and existent but less developed explicit memory.

Clearly, some aspects of children's memory are similar to that of adults, while other aspects are not. Aspects of memory change during childhood not only in quantity, but also in quality. It could also be asked if the memory of young children is more similar to that of healthy adults, or of impaired adults. One paradigm that shows an interesting difference between memory in amnesic and healthy adults is the errorful vs. errorless learning paradigm.

In 1995 Hamann and Squire tested semantic learning in amnesic patients and a control group. They used two procedures of learning: study-test (errorful) procedure and study only (errorless) procedure. In the errorful procedure, participants saw the first two words of a sentence and were asked to guess the last word (medicine cured?????) in the study phase. All sentences were constructed so that the third word of the sentence was difficult to guess from the first two words. If the participant guessed incorrectly, the correct answer was given (hiccups). In contrast, in the errorless procedure, participants saw the whole sentence (medicine cured hiccups) in the study phase. The memory of the last word in each sentence was tested using cued recall, with the first two words of each sentence being the cue. Hamann and Squire found that whereas healthy participants showed better memory under the errorful procedure, amnesic patients showed better memory under the errorless procedure. [The errorful procedure benefit healthy adults may hold true for semantic learning, but not in lexical learning (Cyr and Anderson, 2014).]

There is a debate in the literature as to whether the errorless advantage in amnesic patients stems from implicit or residual explicit abilities. Tailby and Haslam (2003) used a more elaborate self-generation version of the errorless paradigm (they gave participants elaborate clues to the guessed words, e.g., I'm thinking of a five letter word beginning with BR and this word describes a food made of flour, liquid and yeast which is baked and then sliced to make sandwiches). They found that, as expected, severely and moderately memory impaired participants showed better memory under the errorless procedure than under an errorful procedure but they also found that the self-generation paradigm improved the memory in the errorless procedure of those participants. In their view, this finding supports the idea that the errorless benefit in amnesic learning reflects the operation of residual explicit memory processes since it is influenced by level of processing. In contrast, Page, Wilson, Shiel, Carter and Norris (2006) found that the errorless advantage for severely and moderately memory impaired participants was shown under both an implicit and an explicit task. They argue that their findings suggest that preserved implicit memory, in the absence of explicit memory, is sufficient for an errorless advantage to emerge.

To the best of our knowledge, the errorless and errorful paradigm has been used only twice with children. Haslam, Bazen-Peters and Wright (2012) compared lexical (but not semantic) learning in 12-year-old children with traumatic brain injury to that of controls and found that children with traumatic brain injury remembered better under an errorless procedure, whereas control participants remembered a similar number of words under errorful and errorless procedures. Haslam, Wagner, Wegener and Malouf (2015) tested semantic memory of 12-year-old children with traumatic brain injury at different intervals and again, these children showed better memory under an errorless procedure, regardless of the time elapsed between study and test. Unfortunately, that study did not employ a control group. Thus, to our knowledge, there have not been any studies that tested semantic learning under errorful and errorless procedures in healthy children. Moreover, previous studies showed that adults show errorful advantage in learning (e.g., Hamann & Squire, 1995; Cyr & Anderson, 2014), but there have not been any studies that tested at what age this errorful benefit emerges.

The age at which the errorful benefit emerges might thus help us understand the nature of errorless advantage over errorful procedure in amnesic adults. If an errorless advantage appears only under conditions in which there is virtually no explicit memory,