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PAPER

Developmental changes in source memory

Anna B. Drummey and Nora S. Newcombe

Department of Psychology, Temple University, Philadelphia, USA

Abstract

Remembering how one learned a fact can be important in itself (e.g. for considering the value of information). However, source memory is also important, along with the temporal and perceptual information on which it is based, in giving memory an episodic or autobiographical quality. The present study investigated developmental changes in children's ability to monitor source, in a paradigm adapted from Schacter, Harbluk and McLachlan (1984). This task, unlike previous source monitoring tasks used with children, has the potential to show the existence of a serious kind of source error called source amnesia. Children of 4, 6 and 8 years participated. They also completed measures believed to assess prefrontal function. Children showed a steady improvement with age in their ability to remember facts, but showed abrupt improvement between 4 and 6 years in their ability to monitor the source of those facts. Most notably, 4-year-old children displayed a great deal of source amnesia (i.e. errors of the kind committed by populations with frontal dysfunction), but 6- and 8-year-old children showed very few such errors. In addition, source memory was related, in some analyses although not in others, to behavioral measures often used to assess prefrontal functioning. The timing of the transition in source monitoring ability is discussed, including implications for childhood amnesia.

Introduction

Since the time of Freud, psychologists have been interested in the fact that adults usually have spotty and imperfect memories for their early childhood. This phenomenon has been called infantile or childhood amnesia. But although the terms 'infantile' and 'childhood' amnesia are often used synonymously, there may actually be two distinct phenomena captured by these two different phrases. While people rarely if ever remember any events from infancy, they can sometimes retrieve at least fragmentary memories of events occurring when they were 2 years of age and older, months or even years later. The probability of remembering events increases linearly as the age at occurrence of the events goes from 2 to 6 years (Eacott & Crawley, 1998; Sheingold & Tenney, 1982; Usher & Neisser, 1993; see reviews by Howe & Courage, 1993, 1997). Thus, there may be important contrasts among three periods of life: memory for the first two years, memory for the period between 2 and 6 years, and memory thereafter. There is as yet no definitive explanation of infantile amnesia (i.e. lack of memories for the first two years), although it may depend on the fact that language and a sense of self do not begin to develop until during the second year of life. This paper, however, is concerned with one factor that may contribute to the phenomenon of *childhood* amnesia (i.e. the relatively fragmentary recall of events from the ages between 2 and 6 years).

Exploring childhood amnesia requires precision in defining what kind of memories of childhood are lost or retained. Squire (1992) proposed that memory can be divided into two major components. On the one hand, there is declarative memory, often also referred to as explicit memory, which can be defined as those memories we are able to consciously recollect. Examples include remembering your name or the first time you went to the beach. On the other hand, nondeclarative memory, also known as implicit memory, does not require conscious recollection, but simply refers to situations in which having encountered something leads to an effect on subsequent performance. For example, identification of a picture may be more rapid if one has seen it before, and this effect does not depend on conscious recollection of the picture. Childhood amnesia appears to be confined to declarative memory. Indications of nondeclarative memory can be found in young children even when declarative memory is lacking (Drummey &

Address for correspondence: Nora Newcombe, Department of Psychology, 1701 N 13th Street, Room 565, Temple University, Philadelphia, PA 19122, USA; e-mail: newcombe@astro.temple.edu

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Newcombe, 1995), and nondeclarative memory appears not to grow with age but to be robust from early on (Carroll, Byrne & Kirsner, 1985; Drummey & Newcombe, 1995; Graf, 1990; Greenbaum & Graf, 1989; Naito, 1990; Parkin & Streete, 1988; see Ausley & Guttentag, 1993).

Explicit memory can be further divided into semantic memory (e.g. remembering one's name) and episodic memory (e.g. remembering the first time one went to the beach). Tulving (1983) has defined these terms in the following way, 'Semantic memory refers to a person's abstract timeless knowledge of the world he shares with others, episodic memory is concerned with unique concrete personal experiences dated in the rememberer's past' (Tulving, 1983, p. 1). Deficits in episodic remembering seem to be the core of the phenomenon of childhood amnesia. That is, children do not experience a global lack of explicit memories for this period; indeed, their semantic memories seem to be excellent, as shown for instance by their rapid acquisition of vocabulary. In addition, work on delayed imitation has shown conclusively that some types of explicit memory exist in early childhood and even infancy (e.g. Bauer, Hertsgaard & Dow, 1994; Bauer & Wewerka, 1995; Meltzoff, 1995). However, episodic memory as assessed by laboratory tasks such as free recall or picture recognition, has long been known to develop with age (for a review, see Kail, 1990). It may be that autobiographical memory is similar in crucial ways to such laboratory tasks.

At first glance, this idea may seem far-fetched. Autobiographical memory entails, by definition, that an experience seems a part of one's own personal past, whereas memory tasks such as free recall appear impersonal. However, in recollection of either kind, the fact that one experienced the event oneself is bound to the memory of that event. Free recall requires not just knowing the words (which are already in the vocabulary of the participant) but coding the fact that certain particular words were heard at a certain time in a certain place and in a certain context. Autobiographical memory requires not just knowing the facts of one's life, but remembering also associated information about such matters as emotions and perceptual details. Tulving (1985) labels this ability to remember one's act of experiencing 'autonoetic awareness' or 'self knowing' (see also Perner & Ruffman, 1995; Wheeler, Stuss & Tulving, 1997). Thus, episodic memory, whether autobiographical or not, involves access to details about where, when and with whom the experience took place. Indeed, such details are what establishes the memory as a particular event or episode rather than simply a timeless fact (i.e. a semantic memory).

The ability to specify contextual information surrounding a memory has been labeled source monitoring by Johnson, Hashtroudi and Lindsay (1993). Johnson *et al.* (1993) discuss source monitoring as 'a set of processes involved in making attributions about the origins of memories . . .' (p. 3). In making these attributions, one can utilize several kinds of information including the spatio-temporal context of the memory as well as semantic and perceptual detail from the event. For example, having an episodic memory of going to the zoo involves being able to specify contextual details such as that you went last week, you were with your mother and you wore your favorite red shirt. It is not necessary to remember all of the relevant contextual information from the original episode, but some such information is required to experience episodic recollection. Literally remembering the source of a piece of information (e.g. from whom one learned some information, or whether it really happened or was merely imagined) is one aspect of the wider phenomenon of source monitoring.

If childhood amnesia is linked to the development of source monitoring, and childhood amnesia extends from 2 to 6 years, one would expect to see marked improvement between the ages of 2 and 6 years in source monitoring. Developmental studies of source memory in children younger than 6 years offer support for this proposition in general terms. For example, investigations of children's ability to discriminate between real versus imagined events (a type of source monitoring called reality monitoring) have found that children younger than 6 years seem to have difficulty judging if they performed or imagined an action (Foley, Aman & Gutch, 1987; Foley & Johnson, 1985; Foley, Johnson & Raye, 1983). Similarly, studies of theory of mind, using tasks in which children are probed as to how information they have was acquired, have shown that 3-year-old children often have great difficulty recalling source (Gopnik & Graf, 1988; Perner & Ruffman, 1995; Taylor, Esbensen & Bennett, 1994; Wimmer, Hogrefe & Perner, 1988).

However, the exact nature and time course of improvement in source monitoring is not clear. The theory of mind studies have generally found that deficiencies are concentrated in 3-year-olds, but that 4- and especially 5-year-old children are quite good at specifying how they learned something. Similarly, Welch-Ross (1995) found older preschoolers showed good memory for whether they performed or pretended to perform an action, and Lindsay, Johnson and Kwon (1991) found that 4-year-old children were surprisingly good at a source task, having difficulty recalling source only when they needed to distinguish similar external sources (a pig and a bear puppet speaking in the same voice) but not when the sources were more distinct (when a different voice was used for each puppet). Such an accomplishment seems surprising for children still within the period of

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childhood amnesia, if source monitoring is an aspect of difficulty with episodic remembering.

It is, however, possible that data showing competence in source monitoring at the age of 4 may not be indicative of source monitoring ability as measured in older children or adults. Because of the young age of the children, methodologies usually involve a very limited use of memory, with delays typically being a few minutes, and investigators using forced-choice recognition for source questions. These methodological factors likely make the task considerably easier, and may lead to 4-year-olds appearing to have achieved a level of competence more comparable to older children than they actually have.

In addition, a very important point about prior work is that their forced-choice methodology precluded the appearance of source amnesia, a serious form of problem in specifying source. Schacter, Harbluk and McLachlan (1984) differentiated between source amnesia and source forgetting. Source amnesia occurs when someone does not remember that the fact was learned in the experimental situation at all and incorrectly attributes the fact to a source like a book or television (extraexperimental errors). Source forgetting, by comparison, involves remembering a fact was learned in the experiment but not remembering which of the experimenters imparted the information (intraexperimental errors).

Thus, one aim of the present study was to use a source task new to developmental work, taken from the literature on source amnesia in the elderly and in patients with frontal dysfunction, to chart changes in source monitoring across the age period from 4 to 8 years. In order to investigate source amnesia, we adapted the fictitious fact paradigm used by Schacter *et al.* (1984) with prefrontal patients, for use with children. This paradigm involves teaching facts to people, and then determining whether, for those facts they remember, they also remember the source of the information.

A possible biological mechanism for changes in source and overall episodic memory

It is well known that medial diencephalic structures as well as the temporal lobe are involved in episodic memory (Andreasen, O'Leary, Arndt, Cizadlo, Hurtig, Rezai, Watkins, Ponto & Hichwa, 1995; Buckner, Koutstaal, Schacter, Dale, Rotte & Rosen, 1998; Buckner, Koutstaal, Schacter, Wagner & Rosen, 1998; Buckner, Petersen, Ojemann, Miezin, Squire & Raichle, 1995; Buckner, Raichle, Miezin & Petersen, 1995; Cabeza, Kapur, Craik, McIntosh, Houle & Tulving, 1997; Nyberg, Tulving, Habib, Nilsson, Kapur, Houle, Cabeza & McIntosh, 1995). However, recent evidence has suggested that aspects of explicit memories, and of source memory in particular, may also rely on prefrontal cortex (Janowsky, Shimamura & Squire, 1989; Knowlton & Squire, 1995; Schacter *et al.*, 1984, Senkfor & Van Petten, 1998; Shimamura & Squire, 1987, 1991; Squire & Knowlton, 1995; Wilding, 1999). Patients with prefrontal damage have been found to be more likely than normal controls to suffer from source amnesia (Janowsky *et al.*, 1989; Schacter *et al.*, 1984; Shimamura & Squire, 1987). Elderly individuals, who are more likely than younger people to suffer from subtle difficulties with frontal function, have also been found to be more likely than younger adults to make source errors (Craik, Morris, Morris & Loewen, 1990; McIntyre & Craik, 1987). The link between source monitoring and frontal function comes both from levels and patterns of performance in patient and elderly groups, and also, in some cases, from correlations of source monitoring with performance on tasks thought to assess prefrontal function (e.g. the Wisconsin Card Sorting Test or WCST) (Craik *et al.*, 1990; Glisky, Polster & Routhieaux, 1995; Schacter *et al.*, 1984; Schacter, Kaszniak, Kihlstrom & Valdiserri, 1991; Spencer & Raz, 1994).

Building on work of this kind, Schacter, Kagan and Leichtman (1995; see also Leichtman, Morse, Dixon & Spiegel, 2000; Ruffman, Rustin, Garnham & Parkin, 2001) have suggested that deficits in source memory in young children can be linked to the fact that the prefrontal cortex is still developing in the first decade of life. Studies of executive functioning in childhood have shown that activities generally linked to prefrontal brain areas, including goal-directed behavior, planning, inhibition and flexibility, improve through the preschool years (see review by Zelazo, Carter, Resnick & Frye, 1996), although improvement also continues through the elementary school years (Becker, Isaac & Hynd, 1987; Chelune & Baer, 1986; Passler, Isaac & Hynd, 1985; Welsh, Pennington & Groissier, 1991). In addition, direct observation of synaptic connections in humans has shown that the pruning that follows an initial overproduction of synapses in all brain areas continues for an especially lengthy period in prefrontal cortex, not reaching adult levels until adolescence (Huttenlocher, 1979, 1990). Elman, Bates, Johnson, Karmiloff-Smith, Parisi and Plunkett (1996) have argued that there are parallel data from metabolic work with living humans (Chugani, Phelps & Mazziotta, 1987) and that apparently different developmental curves found in rhesus monkeys (Rakic, Bourgeois, Eckenhoff, Zecevic & Goldman-Rakic, 1986) may be due to species differences.

Thus, a second aim of the present study was to examine the nature of the links between changes in source monitoring and prefrontal functioning, in two ways.

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First, the paradigm used allowed for the observation of extraexperimental errors, the kind of error that may be distinctively associated with prefrontal dysfunction (Schacter *et al.*, 1984). Second, we also used a correlational strategy, examining whether putative measures of prefrontal function would be correlated with children's memory for source information. The Wisconsin Card Sorting Test, Verbal Fluency and Stroop tasks have all been used to tap prefrontal function in adults, having been shown to be differentially impaired in individuals with disruption to prefrontal cortex (Koren, Seidman, Harrison, Lyons, Kremen, Caplan, Goldstein, Faraone & Tsuang, 1998; Perret, 1974; Regard, 1981; Stuss, Alexander, Hamer, Palumbo, Dempster, Binns, Levine & Izukawa, 1998). Each of them also exists in a form developed to be suitable for administration to preschool children (Diamond & Boyer, 1988; Gerstadt, Hong & Diamond, 1994; Spreen & Strauss, 1991).

Method

Participants

Participants in the main study were 167 children divided into three age groups: 4, 6 and 8 years of age. There were 70 4-year-olds ($M = 4;5$, range = 4;1–5;0) including 41 girls and 29 boys, 50 6-year-olds ($M = 6;6$, range = 6;3–7;1) including 26 girls and 24 boys, and 47 8-year-olds ($M = 8;2$, range = 7;11–8;8) including 27 girls and 20 boys. Children were recruited from the suburbs of Philadelphia and informed consent was obtained for all participants.

Procedure

All children participated in three tasks administered over two sessions. Each session took approximately 30 minutes. A source task was administered in two parts, with a week delay between sessions; other tasks given to all age groups included a category generation task and a modified version of the Wisconsin Card Sorting Test (WCST). In addition, 4-year-old children had a third session in which they were given several other measures, including a perceptual facilitation task, a Stroop-like Day/Night task and the information section of the WPPSI-R (Wechsler, 1989).[1] Tasks are described in detail below.

[1] All tasks were not given to all age groups for theoretical and/or practical reasons. First, some tasks are not appropriate for the older children. Second, 6- and 8-year-old children are in school and it is difficult to demand a significant amount of time for conducting studies.

The source task

This task, adapted for children for this experiment, was based on a paradigm developed by Schacter *et al.* (1984) to measure the ability to recall the source of remembered information. The task was divided into two sessions. In the first session, children were presented with ten facts concerning a variety of topics. Facts were given by one of two sources, the experimenter or a puppet; both were introduced in the beginning of the session. To be sure the child did not already know the fact prior to the experimental session, facts were asked in the form of a question. For example, 'What animal cannot make any sounds?' If the child did not know the answer, the fact was stated, 'A giraffe cannot make any sounds.' This continued until ten novel facts were given, five by the experimenter and five by the puppet. The facts were then repeated in random sequence.

After a 1-week delay, the second session began by telling children that the experimenter would like to ask them some questions. Ten facts concerned those presented in session 1 and five facts were novel, but of equal difficulty. The remaining five facts were intended to be easy facts children learned outside the experiment. Questions were asked in random sequence. If children responded to a fact question correctly, they were asked where the information was learned. If children were not able to recall the facts, a four-alternative forced-choice recognition test was given. Following this assessment of fact recall/recognition, the source question was asked. If children failed to answer the source question correctly, a four-alternative forced choice was given. Possible sources on the source recognition test were parents, teacher, experimenter or puppet.

Source errors children made were classified in two ways. Extraexperimental errors were those when children indicated they learned the fact from outside the experimental situation (i.e. from a teacher or parent). Intraexperimental errors were those when children erroneously attributed the fact to the puppet when in fact the experimenter presented the fact or vice versa.

Putative prefrontal measures

Category generation task

This task is based on a more general version of the verbal fluency task which requires participants to generate and execute a plan and inhibit the tendency to repeat items already stated. Children were asked to name as many items of a particular category as they could in a 1-minute period. The first category given was fruits and vegetables. The second category was

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animals. Items were recorded with a micro-cassette recorder and the total number of items generated was calculated.

A Modified Wisconsin Card Sorting Test (WCST)

Theoretically, this test assesses regulation of goal directed activity and impulsive responding, functions believed to be mediated by the prefrontal area (Chelune & Baer, 1986). Although the test has been traditionally used to diagnose patients with frontal lobe lesions, Diamond and Boyer (1988) adapted this version for young children. Children are presented with three colored shapes, a blue triangle, a green cross and a red circle. The experimenter explains the model cards as having two characteristics: shape and color. The child is then presented with colored shape cards to sort according to one of these criteria. The child is not informed whether they should sort by shape or color. Rather, participants must infer the sorting rule based on being told whether their response is correct or incorrect. This is presented as a guessing game. That is, the experimenter says that one of the criteria is being used, but the child must guess which one. After the child has correctly sorted five consecutive cards, the criterion is switched without an indication to the child. A testing session lasts until the child has successfully achieved five categories (3 color categories and 2 shape categories) or until 63 cards are sorted.

There are numerous variables that can be examined on the WCST with a high degree of correlation among them. Thus, we created a composite variable by transforming the following variables into *z*-scores and averaging the scores into one overall variable: total percent correct, total percent errors, percent perseverative errors, percent non-perseverative errors, number of trials to complete the first category and number of categories completed.

The Stroop-like day/night task

This task was adapted for children from the Stroop task (Stroop, 1935) by Gerstadt *et al.* (1994) and is only appropriate for the 4-year-old group as children reach ceiling performance around the age of 5 years. The task involves sorting one set of cards. Some of the cards are white with a picture of a sun; the other cards are black with a depiction of a moon and stars. Children are required to identify the white cards as night and the black cards as day. After two consecutive correct trials, it is assumed children understand the rules and 16 cards are sorted and labeled. The number of correct and incorrect identifications was recorded.

Additional measures only given to 4-year-old children

Perceptual facilitation task

This task was developed by Drummey and Newcombe (1995) as an index of implicit memory, specifically perceptual priming. Similar to the source task previously discussed, this task was divided into two sessions with no mention of the first phase of the experiment during the second session. In session 1, children were read a book composed of 10 animal pictures and ten number pages. Preceding each animal page, there was a number page in the color and numerosity of the animal to appear on the following page. For example, a page had a brown-colored 4 and the next page was a picture of four brown bears. In the second session, participants were shown 20 animal pictures (ten of which they had seen in session 1 and ten never seen before). Using an overhead projector, pictures were shown in a range of one to seven on a blurriness scale with one being the most blurry. The children were asked to guess what the picture was as soon as possible. If they indicated the picture was too blurry, the experimenter made the picture clearer until the animal was identified. The level of identification was recorded for each picture. Mean levels of identifications were computed for pictures seen versus those not seen before.

The information subtest of the WPPSI-R

This task was chosen as an index of semantic memory. The first section entailed showing children a stimulus book, which had several items, pictured on a page. They were then asked a question concerning one of the items, such as 'Which of these items do you cook on?' (official manual). Three picture items were completed and then children were asked questions verbally, e.g. 'How many legs does a bird have?' Children were given one point for every correct response and zero for incorrect responses.

Results

Source data

The first objective of this study was to develop a new source task, based on prior studies with individuals with prefrontal damage who show source amnesia (Schacter *et al.*, 1984), to chart changes in source monitoring between the ages of 4 and 8 years. Means for the source task can be found in Table 1. An overall multivariate analysis of variance with age (4, 6 and 8) as a between-subjects factor, and fact recall, fact knowledge, correct

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Table 1 *Mean percent correct and standard deviations for the source task*

	4-year-olds	6-year-olds	8-year-olds
Fact recall	23.1 (16.8)	32.0 (17.4)	50.9 (14.7)
Fact knowledge	68.4 (18.0)	72.2 (20.1)	92.4 (10.9)
Correct source	24.1 (23.2)	46.8 (20.3)	40.4 (20.9)
Extraexperimental errors	59.2 (34.2)	12.7 (22.3)	18.5 (23.6)
Intraexperimental errors	11.1 (14.8)	39.2 (18.3)	39.4 (18.3)

source judgments, extraexperimental errors and intraexperimental errors as dependent variables showed a main effect of age, $F(10, 320) = 19.55$, $p < 0.0001$.

Follow-up univariate analyses of variance were conducted for each variable on the source task separately. Measures of children's fact recall and of their fact knowledge (recall plus recognition) for the facts presented 1 week earlier showed main effects for age on both measures, $F(2, 164) = 40.65$ and $F(2, 164) = 29.94$ respectively, both $p < 0.0001$. Post hoc analyses using the Bonferroni adjustment for multiple comparisons (as did all subsequent such tests) showed either steady improvement across the age range or improvement focused on the 6- to 8-year period. For fact recall, there was steady improvement: 6-year-olds did better than 4-year-olds, and 8-year-olds did better than either younger group. For fact knowledge, improvement was focused on the 6- to 8-year gap: 6-year-olds did not perform better than 4-year-old children, but 8-year-olds did better than either group of younger children.

Measures of the ability to monitor source also showed significant main effects of age, but post hoc tests showed a different pattern of age-related improvement, focused on the 4- to 6-year period. For correct source judgments, the main effect of age, $F(2, 164) = 17.53$, $p < 0.0001$, was due to the fact that 4-year-old children did significantly worse than 6- and 8-year-olds. However, 6- and 8-year-olds did not differ from each other. This pattern of results also appeared for extraexperimental and intraexperimental errors, $F(2, 164) = 49.08$ and $F(2, 164) = 56.33$, both $p < 0.0001$. Thus, it appears that an important and dramatic change in children's ability to monitor the source of information occurs between 4 and 6 years of age.

One important objection to the data concerning the source tasks is whether younger children might potentially know the source but not understand the instructions or lack the ability to verbalize the source of their knowledge. It is known, predominantly from the theory of mind literature, that children sometimes have difficulty stating where or how they acquired information (Diamond, Towle & Boyer, 1994; Taylor *et al.*, 1994; Wimmer *et al.*, 1988). In order to assess whether children's performance on the main task was a measure of their source memory, we tested two small groups of 4-year-old children in modified versions of the source task in which testing was more immediate.

Table 2 *Means and standard deviations for prefrontal measures*

	4-year-olds	6-year-olds	8-year-olds
Category generation	16 (6)	20 (6)	29 (7)
Stroop-like day/night	11 (5)	*	*
WCST			
Total # correct	37 (8)	39 (8)	40 (8)
Total # errors	22 (7)	21 (8)	20 (8)
% Errors	37 (11)	35 (13)	34 (13)
% Persev errors	31 (10)	28 (8)	28 (13)
Categories com	3 (3)	3 (2)	3 (2)
Trials to 1st	13 (9)	24 (18)	22 (20)

Note: *Indicates measure was not appropriate for older children, % Persev = Percentage of perseverative errors, Categories com = number of categories completed, Trials to 1st = number of trials until first category was completed.

First, ten 4-year-old children were given the source task with no delay between fact presentation and source questioning. In this immediate-test group, children had virtually no extraexperimental errors (2%). A second group of nine 4-year-old children were given the same source task with a delay of 5 minutes between presentation of all the facts and the subsequent source test. Although their memory began to deteriorate, children were still very good at specifying the source of the information, making only 13% extraexperimental errors. These data allow us to comfortably attribute the high rate at which 4-year-old children made extraexperimental errors in the main experiment to source memory issues rather than an inability to articulate where or how information was learned.

Correlational data

The second objective of the study was to investigate if children's ability to monitor the source of information was related to putative measures of prefrontal function. (Means and standard deviations for these measures are found in Table 2.) The beginning step in this investigation was to determine what changes occur across age in the latter measures, and whether they are related to each other. Analysis of variance on the number of items generated in the category generation task showed a significant main effect of age, $F(2, 164) = 59.72$, $p < 0.0001$. The means for the 4-, 6- and 8-year-olds were 15.7, 20.0 and 28.7, respectively. Post hoc analyses showed that 6-year-olds generated more items than 4-year-olds, $t(1, 118) = 3.97$, and 8-year-olds generated more items than either younger group, $t(1, 115) = 10.61$ and $t(1, 95) =$

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6.45, all $p < 0.001$. Surprisingly, a similar ANOVA on the modified Wisconsin Card Sorting Test did not reveal any differences across age. The lack of expected age differences may be an indication that the modification of the measure was not appropriate for the 6- and 8-year-old children in this study. Given this finding, and the fact that the Stroop-like day/night task was not given to 6- or to 8-year-olds, the question of correlations among putative prefrontal variables could only be examined for the 4-year-olds. For this group, there was one significant correlation among three: the day-night task was found to be related to category generation, $r = 0.28$, $p < 0.05$. However, this correlation seemed more likely due to general intelligence that to correlation between measures of frontal function, because partialling the WPPSI scale reduced the correlation to $r = 0.16$, a nonsignificant value. Given the independence among the three measures, relations to the source task were examined separately for each.

In 4-year-old children, the category generation task was significantly related to children's fact recall and fact knowledge, $r = 0.36$, $p < 0.01$ and $r = 0.29$, $p < 0.05$, but there were no correlations with source memory. The other two variables, WCST and the day/night task, showed no correlations with any of the memory measures. Thus, this pattern of results was quite different from that found by Glisky *et al.* (1995) in a study of the elderly, or from the pattern expected from work with patients with prefrontal damage.

However, a large number of the 4-year-old children were not merely poor at monitoring the source of information but committed extraexperimental errors all or almost all of the time; for this group, there was, arguably, no meaningful variance. Thus, correlations were also computed including only those children with less than 75% extraexperimental errors ($n = 38$ of the original 70 children, i.e. essentially a median split). Fact recall and fact knowledge remained significantly correlated with category generation, but in this sub-sample, the composite WCST variable was also negatively correlated with the percentage of extraexperimental errors, $r = -0.41$, $p < 0.01$.[2]

An important question is whether any or all of these three correlations were due to overall intelligence, because scores on the WPPSI-R Information section were related to fact memory, fact knowledge and the source measures, although not to the WCST. Partialing WPSSI-R Information, for the subgroup of children with less than 75% extraexperimental errors, in fact eliminated the significant correlations of category generation with fact recall and fact knowledge, reducing these relations to $r = 0.19$ and $r = 0.16$, respectively. However, the WCST variable remained significantly negatively correlated with the percentage of extraexperimental errors, $r = -0.33$, $p < 0.05$. (In addition, WCST was now, oddly, negatively correlated with fact knowledge, $r = -0.33$, $p < 0.05$, although not correlated with fact recall, $r = 0.01$.) Thus, overall intelligence does not seem to account for the connection between children's ability to monitor source and prefrontal function as measured by the WCST, and there is an indication of the kind of differential finding found in work with the elderly and with patients with prefrontal damage.

For older children, category generation was the only putative prefrontal measure. For 6-year-olds, there were no significant relations between the number of items generated in the category generation task and the source task. For 8-year-olds, as for the 4-year-olds, the number of items generated was significantly related to fact recall, $r = 0.34$, $p < 0.01$ and fact knowledge, $r = 0.31$, $p < 0.05$. Furthermore, the category generation task was related to the ability to correctly monitor the source of information, $r = 0.30$, $p < 0.05$, and to the number of intraexperimental errors, $r = 0.32$, $p < 0.05$. There was virtually no correlation between category generation and extraexperimental errors, but this is not surprising because 8-year-olds were committing very few of these errors. Unfortunately, no measure of general intelligence was available, so that the pattern of relations controlling for intelligence could not be examined.

The 4-year-olds also performed a perceptual facilitation task. Consistent with the literature, pictures seen before were named more easily than new pictures, $t(1, 69) = 18.69$, $p < 0.001$. Uniformly nonsignificant correlations with other measures supported the independence of perceptual facilitation from explicit memory, including source monitoring, as well as from intelligence as assessed by WPPSI Information.

Discussion

Source data

Previous studies of children's ability to remember the source of information have produced somewhat conflicting results. Paradigms used to investigate development of theory of mind frequently show incompetent

[2] A WCST composite variable was calculated by using a well-known z-score method of aggregating results to achieve a more reliable statistic given the large number of variables in this task. However, as a point of reference, the number of categories completed variable was the most significantly correlated with extraexperimental errors, $p < 0.02$ and percentage of perseverative errors showed a trend toward significance, $p < 0.2$.

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performance by 3-year-olds and excellent performance by 4- and 5-year-olds. Similarly, 4-year-old children often do well in more traditional source monitoring tasks (Lindsay *et al.*, 1991; Welch-Ross, 1995). Such an early transition to an ability to remember source fits poorly with the proposition that source monitoring is one manifestation of a difficulty with episodic memory, a difficulty that can be conceptualized more broadly as involving the binding together of various aspects of an event (e.g. perceptual, semantic and emotional).

In this study, using an adaptation of the fictitious fact paradigm previously used with patients with brain damage and elderly individuals (Janowsky *et al.*, 1989; Schacter *et al.*, 1984), the data showed a different pattern of developmental change. Children's source monitoring abilities seemed to undergo a dramatic shift between the ages of 4 and 6 years. An especially striking feature of the 4-year-old children's performance was that the kind of errors these children made were indicative of what Schacter *et al.* (1984) have termed source amnesia, not merely source forgetting. The children were not simply forgetting whether it was a puppet or the experimenter who relayed a particular fact; rather, 60% of the time, they seemed to completely forget the context of the experiment, attributing the facts to other, extraexperimental sources. Their responses were not a stereotyped default response, such as 'mother', but involved a variety of family, teacher and media sources. Moreover, another important feature of the data was that these kinds of errors were virtually nonexistent in children 6 years of age, and there was no hint of age-related change in source performance between 6 and 8 years, even though their performance was far from ceiling levels. In addition, data from children tested immediately or after 5 minutes showed that lack of understanding of instructions or lack of ability to verbalize did not account for performance. Thus, these data strongly suggest 4-year-olds show significant deficits in source memory.

These findings of poor performance of 4-year-olds in a source monitoring task are discrepant with studies showing competence by this age. However, there may be at least two explanations for this difference. First, in the vast majority of the theory of mind studies, children were not given the opportunity to display source amnesia (Gopnik & Graf, 1988; Lindsay *et al.*, 1991; Perner & Ruffman, 1995; Taylor *et al.*, 1994; Welsh-Ross, 1995; Wimmer *et al.*, 1988). For example, in the Welsh-Ross (1995) study, children were asked in a forced-choice task whether they had performed, imagined or pretended actions. While it would be difficult to ask these kinds of source questions in a standard recall format, using forced choice allows children to realize that some of these actions must be from each category. The fictitious fact paradigm, in contrast, is advantageous because children can be asked to recall facts and the source of those facts in a very naturalistic and open-ended way, allowing an exploration into the kinds of errors children make rather than just the quantity of errors.

A second possible reason why 4-year-olds had difficulty remembering source information in the present study is that we imposed a 1-week delay between experimental sessions. Delays in most other studies usually do not exceed a few minutes. Giving all procedures in a single session obviously does not stress memory to any great degree, and, in addition, may provide an indication to children that answers to the questions must be from within the experimental session. These methodological differences could account for why 4-year-olds succeed in previous source monitoring situations but not in this one.

One might ask why fact memory showed improvement between 4 and 8 years of age, as well as source memory. This finding differs from that in frontal patients, who have little difficulty with fact recall while showing source amnesia (Janowsky *et al.*, 1989; Schacter *et al.*, 1984). However, a large number of studies show improvement in recall memory across these ages, perhaps due to factors such as a greater amount of background knowledge or the use of mnemonic strategies. We did not predict and in no way wish to imply that semantic memory is age-invariant. Source memory and semantic memory may in fact be closely related. In particular, Marcia Johnson and her coinvestigators (e.g. Johnson *et al.*, 1993) conceptualize source judgments as based on inference from inter-linked semantic memories concerning sensory, semantic and locational aspects of an event. The retention of such bound memories, in their view, is what creates a source memory, or, perhaps better put, the ability to make a source judgment.

Why do error patterns on the source task show a marked change between the ages of 4 and 6 years, with no significant difference between 6 and 8 years of age (despite the absence of ceiling effects)? This pattern might reflect several underlying changes, but there are two prominent possibilities. First, increases in semantic memory could lead to retention of the crucial clues for making source judgments. (Note how semantic and source memory are intertwined in this theorizing.) Second, with age, children might better be able to utilize these clues to make source judgments.

Correlational data

Evidence of source amnesia in 4-year-olds, just discussed, supports the hypothesis of late development of the prefrontal cortex. That is, it is quite suggestive that the source amnesia in 4-year-olds is also exhibited by

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populations identified as having some type of frontal dysfunction. However, correlational evidence of a connection between source monitoring and prefrontal function on a within-person basis was not conclusive. On the positive side, the incidence of extraexperimental errors was significantly correlated with performance on the modified version of the WCST in a subsample of 4-year-old children. Partialing out possible contributions of IQ as measured by the information section of the WPPSI-R did not render this correlation insignificant; indeed, partialing improved the picture by reducing the correlations with fact memory and fact knowledge that one would not have expected on the basis of results from people with prefrontal damage. In addition, category generation correlated with source memory for 8-year-old children. However, on the negative side, it must be acknowledged that predicted correlations of source memory with prefrontal functioning did not appear for 4-year-olds in the full sample, for two of the three putative prefrontal measures even in the subsample of 4-year-olds, or for 6-year-olds.

One can argue, however, that the lack of compelling findings from the correlational analyses stems from problems with the measures, which are highly indirect and likely index functioning of systems outside the prefrontal areas as well as the area of interest (Parkin, 1998). Additionally, different areas of prefrontal cortex may be required for different tasks, and there is of course no guarantee that prefrontal development is uniform across the entire cortical area. In fact, conflicting findings from correlational analyses using measures of prefrontal function are a common problem in the literature. For instance, in elderly populations, Craik *et al.* (1990) showed such correlations, but Schacter *et al.* (1991) and Spencer and Raz (1994) found weaker or nonsignificant relations. It may be, however, that a meta-analysis would allow a clearer pattern to emerge. When Newcombe, Sluzenski and Ottinger (under review) meta-analytically combined the results of three studies of 4- and 6-year-olds, they found a set of significant correlations between category fluency measures and effortful memory, after statistical control for verbal ability.

Conclusion

While the present correlational findings can serve only as preliminary evidence for a connection between changes in source monitoring, episodic memory and prefrontal development, the source memory data from the study have direct implications for the phenomenon of childhood amnesia, whatever its neurological substrate. Specifically, source performance made a rather abrupt improvement from 4 to 6 years, and showed little change subsequent to that time. Thus, it is plausible that the fact that children seem to be able to recollect autobiographical memories with much greater accuracy after the age of 5 or 6 years, as shown by Wetzler and Sweeney (1986) and others, may be linked to children's increased ability to monitor the source of information. The nature of this link remains to be specified.

One way to think about the link between autobiographical memory and source monitoring is that both depend on binding together a rich array of various kinds of information about an event. In the context of the paradigm used in this study, memory for source may be derived from memory for perceptual detail regarding voice and appearance. Children who gave extraexperimental sources may not have any of these aspects of the original event available, either because they were not encoded initially, or because they were not bound together with the fact information, so that the two kinds of information are not necessarily retrieved together. In this way of thinking, the extraexperimental errors are essentially confabulations. Similarly, memory is not episodic or autobiographical unless a sufficient number of aspects of the event can be remembered so that it seems unique and vivid (in Tulving's terms, so that it involved 'mental time travel'). Thought of this way, source memory is not important in and of itself. It is just that it is based on some of the aspects of an event that, if encoded, bound together with other information, retained and retrieved, give memory an autobiographical quality.

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