

To Have and Have Not:

What Do We Mean When We Talk About Long-Term Memory Development?

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When we look at babies in their cradles or their car seats or their parents' arms, we wonder what they make of their experience, and what they will retain of what goes on around them. Opinions on this issue vary widely, with some observers claiming that early memories vanish quickly, if they are ever formed at all, and others arguing that infant memories are formed easily, are retained forever and are profoundly influential on adult personality. While researchers are working hard on understanding early memory, extreme points of view co-exist in popular sources. In a few cases, this public discourse has involved citation of professional papers—although sometimes in opposite ways. For example, Carolyn Rovee-Collier's extensive work with the mobile conjugate reinforcement paradigm has been used both to bolster the notion that babies forget and to support the idea of life-long influence of infant experience.

On the forgetting side, one father keeping a blog on his infant son cited Hill, Borovsky and Rovee-Collier (1988):

I am fascinated by everything about Owen's development. Now that he is sitting up on his own and crawling, the next step he has been working on is going from a sitting position to crawling. This has been a challenge for him, and no matter how close we are to him, he seems to quickly end up in a face-plant when he tries this. So, poor little Owen sits, thinks about crawling, even sways forward a little, but chickens out almost every

time. It got me thinking about infant memory and how long the memories of the face-plants would last for Owen before he got brave enough to try again. I found this interesting study on infant memory development which basically says there's 2-3 weeks before babies forget. Well, we must have reached that mark, because Owen is now moving from sitting to crawling with ease, just since this morning. Ah, the sweet freedom of having Owen sit and play and remain stationary is gone . . .

(<http://www.bloggingbaby.com/entry/1234000457048991/>)

Owen's father interprets Rovee-Collier's work as telling him about forgetting. On the other hand, on a web page advancing the view that infants form long-lasting memories from the start of life, including influential memories of birth and of circumcision, David B. Chamberlain, Ph.D., also cites work by Rovee-Collier (as well as by Patricia Bauer and Andrew Meltzoff), in arguing that:

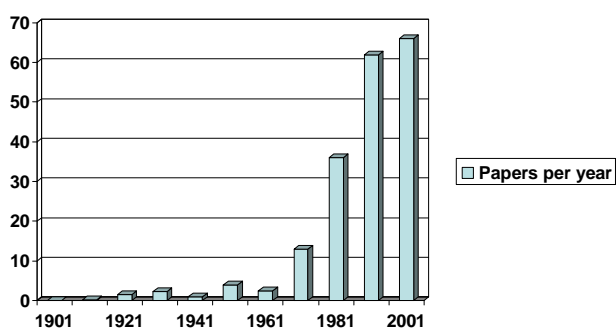
[T]wo- and three-year old children [can recall] specifics of their birth when they are first able to speak. This evidence, published in magazines for childbirth educators and parents in 1981, was never taken seriously in scientific circles. Ironically, for the last 16 years, we have had memory experts denying birth memory while new waves of three-year-olds were proving them wrong!.... What the experimental psychologists have [now] managed (against heavy odds) to prove is that children age three, age two, and age one are all capable of both immediate and long-term recall of specific events in their lives. Infants tested at two, four, and six months can recall details about hidden objects, their location, and size.....The old belief that infants are mentally incompetent has isolated them and delayed discovery of their elementary abilities. More importantly, this belief has obscured the evidence for higher perception, telepathic communication, and subtle forms

of knowing which we have discovered in various forms of psychotherapy. With another big barrier down, perhaps parents and professionals will be able to meet real babies more often. (<http://www.birthpsychology.com/birthscene/intelligent2.html>)

While it is always gratifying to have the public interested in science, the ease with which the same evidence can be used to contrasting ends is humbling. Some psychologists may be tempted to dismiss these uses of their work as the consequence of misunderstanding, poor communication, or people having axes to grind, but before we wave away these comments as inconsequential, we should consider what message we are transmitting. For several decades, much research in cognitive development, including infant memory development, has revolved around the question of “When do children of age X have ability Y, and how do they get it?” A question of this form seems simple and potentially answerable, but it masks quagmires of uncertainty. Most notably, what do we mean by “have”, how do we ascertain if “ability Y” is a natural kind, i.e., a productive analytic entity about whose nature it makes sense to inquire, and can we answer “how do they get it” in a fashion that does not involve infinite regress, reductionism, invocation of homunculi or appeal to abstract principles that are hard to translate into specifics? We will organize our commentary around these three questions, beginning with the second one because there is a great deal to say about the nature of memory abilities. There are many different kinds of memory, most notably explicit and implicit memory and, within explicit memory, semantic and episodic memory. (These distinctions are ones that Owen’s father and Dr. Chamberlain do not take into account.) We will go on to discuss what we mean when we speak of children “having” an ability at a certain age, and finally to discuss the question of mechanism.

Before tackling this agenda, however, we want to begin by applauding what the authors of the four chapters in this section have accomplished, and what Lisa Oakes and Patricia Bauer have achieved in assembling this book. The contributors all report exciting, ingenious and thoughtful research programs on infants' and young children's long-term memory. Collectively,

Growth in Infant Memory Research



this work gives us a “great leap forward” toward an understanding of when memory develops, what develops in memory, how memory develops, and why certain memory abilities develop at specific points in development. The volume appears at an important time for taking stock of knowledge about infant

memory, because knowledge in the area has been exploding. In Figure 1, we have charted the number of papers per year appearing on the topic, as judged by a search of the PsychInfo data base for past decades beginning with 1901-1910. Clearly, active interest in the topic did not begin until around 1971, despite the early pioneering work of Robert Fantz. There was an acceleration of interest beginning in 1981, but only in the past 15 years or so have we seen real waves of excitement about research in infant memory. As points of contact with cognitive psychology and cognitive neuroscience grow, and methodological advances come at an accelerating pace, it is an excellent moment to evaluate what we know and what we need to find out about early memory development.

<1>Kinds of Memory: Explicit and Implicit Memory in Infancy

As recently as 20 years ago or so, investigators drew few distinctions between types of memory in infancy and early childhood, or, perhaps, distinguished primarily between recognition and recall (e.g., Brody, 1981). However, during the eighties there was a revolution in the adult memory literature leading to the view, now widely accepted, that there are crucial distinctions to be drawn between explicit (or declarative) memory and implicit (or procedural) memory, and that these different types of memory systems are supported by different neural substrates, serve different functions, and operate according to different rules (for examples of recent discussions, see Schacter, Wagner, & Buckner, 2000; Squire, 2004). *Explicit* memory refers to the recognition or recall of objects or events that are available to consciousness. In contrast, *implicit* memory refers to memory that is inaccessible to consciousness. Included under the umbrella of implicit memory are several different kinds of memory, including motor skills (e.g., how to ride a bicycle), classical conditioning, and priming.

The distinction between explicit and implicit memory is harder to work with in investigating infant memory than in examining adult memory. Explicit memory is available to consciousness and, in adult research, is often assessed through verbal reports. Because infants cannot speak, researchers are challenged with designing procedures that tap explicit memory, but do not require verbal instruction or verbal expression. Naturally, there can be debate as to whether this goal has been successfully accomplished. This book contains two pairs of chapters on two techniques that investigators have claimed tap explicit memory in infancy: the visual-paired comparison task and imitation-based tasks. In each case, there has been debate concerning whether the non-verbal procedures used are actually assessing explicit memory, and hence about when we first see evidence of explicit memory in human development. The chapters also touch, although in a less focused way, on a third technique about whose meaning there has also been

controversy, namely the mobile reinforcement paradigm. In this section, we assess the state of the current evidence.

<2>Does Visual Paired Comparison Index Explicit Memory?

The visual-paired comparison task (VPC) used to study infant memory is based on visual preference techniques originally developed to examine infant perception (Fantz, 1958). This technique capitalizes on an infant's tendency to orient toward novel stimuli. In the VPC task an infant is pre-exposed to a single visual stimulus for a fixed period of time. After a short delay, the infant is shown a new stimulus and the old stimulus and the looking time to both stimuli is measured. If the infant looks longer at the new stimulus, it is inferred that he or she can discriminate the stimuli, and, more important, has a memory of the old stimulus.

<3>Conflicts in Evaluating the Evidence

Rose, Feldman, and Jankowski argue that VPC is a measure of explicit memory, dependent on the medial temporal lobe and diencephalic structures, including the hippocampus. In contrast, Snyder argues that performance on VPC may reflect an interaction between visual attention and memory, and may actually reflect implicit memory. Rose et al. cite three lines of neuropsychological evidence to support their argument that the VPC task is a measure of explicit memory, each of which is critically analyzed and reinterpreted by Snyder. The first line of evidence comes from studies with non-human primates. Early studies with monkeys showed that large medial-temporal lobe lesions led to impaired performance in VPC in both infant and adult monkeys (Bachevalier, Brickson, & Hagger, 1993). Further studies have supported this conclusion (Pascalis & Bachevalier, 1999; Zola, Squire, Teng, Stefanucci, & Buffalo, 2000). A second line of evidence comes from studies showing that amnesic patients exhibit impaired performance on the VPC task, suggesting that the VPC reflects a form of explicit memory

mediated by a medial-temporal substrate (McKee & Squire, 1993). A third line of evidence comes from behavioral studies with adults. Adults show preferential looking in VPC just as infants do, and, more importantly, their preferences for novelty in VPC were correlated with their confidence ratings regarding traditional recognition responses after a 24-hour delay (Manns, Stark & Squire, 2000).

This is a seemingly robust array of data, but Snyder points out many problems with each of the studies in the edifice. First, studies of both humans and monkeys with damage to the hippocampus turn out not to involve damage exclusively confined to that area. Second, the VPC task used in studies with normal and brain-damaged adults varied significantly from the task used with infants. Adults were required to encode 24 different stimuli at acquisition compared to infants' single stimulus encoding; they were given significantly less time to encode stimuli than infants; and, inevitably, the fact that the stimuli were already known to the adults (but not to the infants) most likely affected the way in which the stimuli were encoded at acquisition and led to the engagement of different processes and neural circuits in adults compared to infants. In light of this evidence, Snyder suggests that the neuropsychological and behavioral data cited by Rose and colleagues do not support their view that novelty preferences in VPC constitute a measure of explicit memory dependent on the hippocampus. Rather, infants' performance in the VPC may be the result of repetition suppression in the visual processing pathway, suggesting that performance in VPC is a measure of implicit memory. There is evidence that the visual system may be biased to the processing of new or not recently seen stimuli, with an associated reduction of neuronal responses in the visual processing pathway with stimulus repetition (Desimone & Duncan, 1995).

There is some hope that recent work measuring the neurophysiological processes that underlie infants' novelty preference in the VPC may provide new understanding of the nature of the memory tapped by the task. ERPs are a measure of the electrical activity of the brain time-locked to the presentation of a stimulus. They are recorded from electrodes placed on the scalp and provide fine-grained temporal resolution of ongoing cognitive processes. ERPs are an excellent tool to use with infants because no physical response from the infant is required. The use of event-related potentials (ERPs) in conjunction with VPC potentially provides a better understanding of what brain areas are involved in infants' preferential-looking. The two sides in the debate over whether infants' novelty preferences indicate explicit memory or result from repetition suppression predict different ERP results. An explicit memory interpretation would predict that novelty preferences would be associated with *increased* amplitudes of ERP components over *anterior frontal-temporal* regions, whereas an implicit memory interpretation would predict that novelty preferences would be associated with *decreased* amplitudes of ERP components over *posterior occipito-temporal* regions.

Unfortunately, results from currently-available ERP studies of this issue do not produce clear results. Infants show increased amplitudes in some ERP components when viewing familiar stimuli (Bauer, Wiebe, Carver, Waters, & Nelson, 20003; Carver, Bauer, & Nelson, 2000; de Haan & Nelson, 1999), which is not a pattern predicted by either side in the debate. However, this research was not specifically aimed at evaluating the VPC task. More recently, Snyder, Stolarova, and Nelson (in preparation) showed that preference for novel faces was associated with decreases in electrical activity over the temporal regions and preference for novel objects was associated with decreased brain activity in the occipito-temporal region. Snyder and colleagues argue that these decreases in neural activity support the hypothesis that novelty

preferences reflect the influence of repetition suppression in the visual pathway, and reflect a form of implicit memory. ERPs clearly hold promise of clarifying the brain bases and essential nature of VPC, but this one study cannot be conclusive, and more studies focused on the issue are needed.

<3>Dual Processes in Infant Recognition Memory?

One of the exciting aspects of the VPC chapters is that both of them make extensive use of data from a variety of literatures using different techniques and different study populations, rather than being confined simply to behavioral studies of infants. However, somewhat oddly, neither article considered the large and potentially highly relevant body of knowledge on recognition memory in normal adults. There is a long-standing and still-raging debate in this literature concerning dual-process versus single-process models of recognition memory. Dual-process theorists argue that adult recognition memory judgments are jointly determined by feelings of familiarity and by specific recollection (for recent views, see Diana, Reder, Arndt & Park, in press; Rotello, Macmillan & Reeder, 2004; Yonelinas, 2002). For example, in Remember/Know paradigms, adults are asked to judge whether they simply “know” (based on feelings of familiarity) or specifically “remember” (recall specific details) when making a recognition judgment. These memory processes may differ in speed (e.g., Hintzman & Caulton, 1997) and specificity of information retrieved (Gardiner, Gawlik, & Richardson-Klavehn, 1994), and they may be supported by different neural mechanisms (Aggleton & Brown, 1999; Curran, 2000; Rugg & Yonelinas, 2003). Single process theorists, on the other hand, suggest that recognition memories simply differ in strength, so that, for example, “remember” responses are made to well-encoded items and “know” responses to less well-known ones (Dunn, 2004;

McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997; Slotnick & Dodson, 2005; Wixted & Stretch, 2004).

These positions have consequences for understanding VPC. If single-process theorists are correct, then VPC performance may well indicate explicit memory in infants. However, the memory might be rather a weak one, especially because differential looking at the two stimuli in this paradigm does not require a definitive “yes-no” response. If dual-process theorists are correct, performance on the VPC task, like performance on standard recognition tests, might be based on a blend of processes, supported in part, or at times, by explicit recollection and also, or at other times, by familiarity. Working out the consequences of dual-process theory of recognition for infant performance in the VPC depends on how one thinks about familiarity. Although older dual-process theories argued that familiarity might be based on implicit memory (e.g., Jacoby, Lindsay & Toth, 1992; Jacoby & Kelley, 1992), most current dual-process theories do not take this position. If feelings of familiarity are based on explicit memory, as they are in contemporary views, then it is natural to suppose that VPC performance would also index explicit memory. Note though that looking in VPC need not involve a recollection component. Thus, the consequences of both single- and dual-process views of adult recognition memory in their current forms would be to suggest that VPC indexes explicit memory, but also to warn us against assuming that such ability is equivalent to adult memory because the explicit memories might either be weak (in single-process terms) or lacking in recollection (in dual-process terms). (This matter is discussed further shortly, in the section on what it means to “have” an ability).

Let us pause, however, to consider whether there might in fact be a “familiarity” process based on implicit memory that is difficult to discern in adults because they have learned to use implicit memory in support of explicit judgments. There are some indications in the literature

that this could be true. For example, in at least one individual with early hippocampal damage, recollection ability was impaired while familiarity-based recognition apparently was not (Bachevalier & Vargha-Khadem, 2005). Furthermore, preschool children seem not to use perceptual fluency (also called processing fluency) as a guide to explicit memory judgments although this mnemonic strategy appears in elementary school children (Drummey & Newcombe, 1995; Guttentag & Dunn, 2003). If one pursues this idea, it could be that there is a truly implicit process available in infants and young children to guide behavior in VPC, as Snyder postulates.

It is an understatement to say that future research is needed. Right now, we know almost nothing about the nature of familiarity, recollection and implicit processing in memory in infancy and childhood. The main point we are trying to make here is that developmentalists need to be aware of the single- and dual-process theories of recognition (and controversy regarding them).

<3>No Bottom Line Yet on the VPC

We believe the debate as to what form of memory the VPC indexes is not yet resolved. But there is reason for optimism that it can be settled, perhaps soon, by further data collection that focuses further on task comparability, careful control (or at least assessment) of areas of brain damage in lesion studies, the further study of behavior in infant monkeys with both intact and lesioned brains, and the utilization of distinctions and insights from the large literature on recognition memory in normal adults. In fact, it is a measure of the scientific maturity of the field of infant memory to see focused and rigorous controversy of the kind we read in the pair of chapters on the VPC task.

<2>Does Deferred Imitation Index Explicit Memory?

The VPC task derived from Fantz' early work, and was already well established in the infant memory literature when the explicit-implicit distinction burst on the scene from the adult memory literature. By contrast, it was only in the late 70s and the early 80s that we became aware of the imitative abilities of infants (Meltzoff & Moore, 1977, 1983), and still later that we learned that infants would imitate actions even with an intervening delay (Meltzoff, 1988), that toddlers could imitate multi-step sequences (Barr, Dowden, & Hayne, 1996; Bauer & Mandler, 1989) and that initial imitation by the infant was not necessary to see retention of the adult's action (Meltzoff, 1995). The appealing feature of imitation-based tasks for assessing early memory is that the measures do not require verbal instructions or a verbal response; rather, memory is inferred from a behavioral response. One limitation to these types of tasks, however, is that they require physical and motor maturity on the part of the infant, so they cannot be used with babies younger than 6 months (at the extreme lower limit).

There are several reasons to argue that imitation-based tasks measure explicit memory. First, explicit memory is the conscious recognition or recall of the content of an experience. Infants' ability to reproduce another person's actions fits this bill. Second, although this measure is non-verbal, the contents of these memories are accessible to language once it begins to be learned (e.g., Bauer, Kroupina, Schwade, Dropik, & Wewerka, 1998). Third, infants learn and remember on the basis of a single experience, which is a characteristic of explicit memory (Bauer & Hertsgaard, 1993). Fourth, memory as tested in the imitation-based task is flexible. For example, infants are able to imitate actions when objects at the time of retrieval are different in various characteristics such as size, shape, color from the objects used at time of encoding (e.g., Bauer & Dow, 1994). Fourth, imitation-based tasks pass the "amnesia test." McDonough, Mandler, McKee, and Squire (1995) tested adults with amnesia and control participants in an

imitation-based task using multi-step sequences. Normal adults were able to perform the model's actions after a delay, whereas the amnesic patients performed poorly. Lastly, imitation-based tasks pass the "parameter filter". This strategy involves assessing the effect of different independent variables on adults' performance on particular tasks. Variables that are thought to influence explicit memory have no effect on implicit memory and vice versa (Richardson-Klavehn & Bjork, 1988; Tulving, 1983). Several studies have shown that similar variables known to affect adults' explicit memory such as age, retention interval, and context change affect infants' memory in imitation-based tasks (see Hayne, 2004 for a review). This evidence suggests that imitation-based tasks are measures of a form of explicit memory.

<2>The Conjugate Mobile Reinforcement Paradigm

Hayne discusses data from the Rovee-Collier paradigm, but research using it is not her major focus. However, Rovee-Collier (1997) has argued at length that infants' behavior in this paradigm indexes explicit memory, and Hayne clearly subscribes to the same view. The evidence is somewhat indirect, however, largely involving analogies and parallelisms between studies of adults' explicit memory and how infants behave with the mobiles. The case is persuasive but not closed, and Bauer, DeBoer and Lukowski (this volume) argue that although reinforcement tasks and imitation-based tasks share similar content, function, and rules of operation, reinforcement tasks, unlike imitation-based tasks, may tap implicit rather than explicit memory. For example, in reinforcement paradigms the test of the infant's memory for order information is whether they change their rate of responding when temporal order is violated. In the imitation-based tasks, on the other hand, temporal order must be encoded during the time of encoding, that is, the order can only be reproduced if encoded in to memory. One problem in evaluating what kind of memory is tapped by operant learning is that there do not appear to be studies with amnesic

adults, imaging studies, or studies with nonhuman animals. The case on whether the mobile conjugate reinforcement paradigm assesses explicit memory remains open.

<2>Interim Summary

Where does this body of data leave the overall question of the developmental origins of explicit memory? There is strong reason to suppose that deferred imitation depends on explicit memory, but uncertainty remains regarding the nature of VPC and the mobile paradigm. Hence, because deferred imitation cannot be used with infants too young to grasp and manipulate objects, we lack definitive evidence regarding explicit memory in the first 6 months of life. Furthermore, and in the big picture more importantly, the earliest appearance of an ability is not equivalent to its robust presence. We should be careful about concluding that explicit memory is present by 6 months or perhaps even earlier, while neglecting data suggesting that it strengthens and changes in subsequent months and years. We will say more about this matter shortly.

<2>A Cautionary Note: Implicit Memory Is Not Permafrost

The focus of these chapters is on when we can first see evidence of explicit memory in infants. The interest is a natural one, since conscious recall seems a hallmark of our everyday existence. But note that popular interest in the retention of infant experience does not focus exclusively on explicit remembering. If the birth process or circumcision affect us, they pretty clearly do not do so because we can consciously or verbally discuss these experiences (although a small minority may claim they can). More plausibly, it might be that what we experience as infants affects our emotions—what we like, what we fear, how trusting or gregarious we are—in an implicit way.

Implicit memory is often conceptualized as more basic and robust than explicit memory, for instance, as not showing developmental change (e.g., Greenbaum & Graf, 1989; Naito, 1990)

and as evident even when explicit memory is lacking, both in amnesics (e.g., Schacter, 1983) and in children (Newcombe & Drumme, 1995; Newcombe & Fox, 1994). There is sometimes also an implication that it does not decay, and yet we know relatively little about how long implicit memory lasts. In the adult literature, the issue has not been very much addressed—“long” delays in these experiments are often no longer than a few hours, but a few studies have shown that implicit memory does seem to decline over longer intervals such as weeks or months (Goshen-Gottstein & Kempinsky, 2001; Willingham & Dumas, 1997). In the developmental literature, although children do seem to act differently in situations depending on whether or not they have experienced them before, in ways more consistent with implicit than explicit memory (Myers, Clifton & Clarkson, 1987; Perris, Myers & Clifton, 1990), studies on memories for preschool classmates have suggested that implicit memory declines over time, even if not to chance levels (Newcombe & Fox, 1994; Lie & Newcombe, 1999). Thus, there is a mixed picture. It is possible that implicit memory of infant experiences can survive to influence behavior, but the influence may not be as strong as is sometimes imagined. This conclusion is quite tentative, however, and again, a call for future research seems an understatement.

<1>Kinds of Memory: Semantic and Episodic Memory

The focus of much attention in studying long-term memory has been on assessing to what extent infants show explicit memory at all. However, although we know that, at least by 6 months, there is some evidence of explicit memory, we know less than we should about a further issue, namely the extent to which these measures of explicit memory tap semantic or episodic memory. Semantic memory refers to knowledge that is general and not necessarily linked to any specific past episode. Episodic memory refers to memory that is specific in nature, that includes the where, when, how and even why of experience. It can be autobiographical in nature when it

involves personally-relevant events. Tulving has called it “autonoetic consciousness” (Tulving, 1985).²

It is possible that memory in infants and toddlers is primarily semantic. Such a developmental pattern would be quite adaptive, as it is clearly more important for young children to learn about the world in a general way than to know just when, where, from whom and so on information was acquired, and it would fit well with Tulving’s speculation that episodic memory grows out of semantic memory (Tulving, 2002). Thinking this way is consistent with findings that semantic memory can be laid down even when episodic memories are not, due to early hippocampal damage (Vargha-Khadem, Gadian, Watkins, Connelly et al., 1997). Further, this hypothesis would help make sense of the fact that children younger than 2 years of age can form explicit memories (as we have seen) and yet, later on, they will not retain memories for autobiographical episodes in their lives (Bruce, Dolan & Phillips-Grant, 2000). Having autobiographical memories may depend on a variety of abilities that take some time to develop, including the strategic recognition that different kinds of semantic memory offer clues as to whether or not an event really occurred (Sluzenski, Newcombe & Ottinger, 2004) and the appearance of processes that bind together the semantic components that make a particular memory distinctive and hence episodic (or if personal, autobiographical) (Sluzenski, Newcombe & Kovacs, in press).

Semantic memory ability may strengthen during early infancy, as we see increasing generalization of memory across contexts. For example, in VPC, infants’ representations become more flexible as they grow older. Rose, Jankowski, and Feldman (2002) found that 7-month-olds familiarized to a face in full frontal view were only able to recognize the face when in a frontal or a $\frac{3}{4}$ pose, whereas 12-month-olds were able to recognize not only the $\frac{3}{4}$ poses, but also other

profiles and rotations of the familiar face. Similarly, but in an older age range, Robinson and Pascalis (2004) recently reported that 12-month-olds failed to treat a picture of an object as familiar in VPC when the backgrounds against which pictures were shown changed, but that 18-month-olds did show recognition independent of background context. Analogous changes from narrowly context-bound memory to more generalizable memory have been found using deferred imitation and mobile reinforcement techniques. The ages and parameters across which such generalization is found vary, but the overall picture is one in which infants become progressively more able to build semantic memories that showed appropriate scope to be serviceable.

Episodic memory involves a different adaptive challenge. Sometimes, while maintaining general knowledge, we also need or want to encode and retain specific contextual details. We want to be able to recognize a person we know from a variety of poses, in a variety of lighting situations, and wearing varied clothing (e.g., we can recognize our friend Olivia whether she is on the beach in bright sunlight or in an elegant dress at night). That's the job of semantic memory. But we also sometimes remember just what that person looked like at a specific point in time (e.g. "Olivia looked lovely in her purple silk dress the Saturday night in July when she and I and Edgar dined in candlelight at the Ritz"). That's what episodic memory does. What we want to know about memory development is when children can *both* remember that they saw an object before, even when it appears in a new context, and *also* remember that they saw it in a particular context at a particular time. The Robinson and Pascalis experiment, and others like it, evaluated only the first ability.

Unfortunately, we do not currently have a paradigm for use with infants and toddlers that is well suited to investigate the existence of early episodic memory. Hayne reports initial exploration of what she calls the "spoon" paradigm, using a name taken from a folk tale cited by

Tulving, for investigating episodic memory early in life. In those studies, 3-year-old children can remember where an object was hidden, what room contained what hidden object, and what order the objects were hidden in. Similar data were actually gathered some time ago with even younger children (DeLoache, 1984). However, we are not sure that these findings indicate episodic memory. Certainly the situation that the children faced was far simpler than that confronted by the birds caching wax worms and peanuts (Clayton, 2004). More work along these lines seems vital.

We speculate that the earliest roots of episodic memory will be found around the second birthday, at roughly the same time that long-lasting autobiographical memories begin to appear. We further speculate that these earliest episodic abilities will be fragile, and that the years between 2 and 6 will see very rapid development in episodic skills. There are several findings consistent with this idea: source memory changes markedly in this age range (Drumme & Newcombe, 2002), as does the ability to determine if an event really occurred or was only imagined (Sluzenski et al., 2004) and the ability to determine if an animal seen before was shown against a background seen before (e.g., not just “I saw a tiger” and “I saw a street scene” but “I did (or did not) see a tiger in the street scene”; Sluzenski et al., in press). The last paradigm is very close to being the “flip side” of Robinson and Pascalis’ study of the ability to recognize objects even when backgrounds change. Children may first acquire the ability to ignore a background in the service of learning about the world (semantic memory), as studied by Robinson and Pascalis, and then later learn to link aspects of that world with other aspects to form episodes. Our last speculation is that this rise in episodic memory is linked to changes in the prefrontal areas of the brain, an idea for which we have gathered some tentative support (Drumme & Newcombe, 2002 Sluzenski et al., 2004).

<1>What Does It Mean To “Have” An Ability?

We have talked a great deal about one of the three questions we raised at the beginning of this chapter, namely, what kinds of memory there are. It is time to turn our attention to another issue, namely what we mean when we say a child “has” an ability. Developmental psychologists are often fascinated with discovering the *earliest* evidence of an ability. For example, Barr, Dowden and Hayne (1996) found that, under the right circumstances, babies as young as 6 months could show deferred imitation. As mentioned above, this important finding marks the earliest point to which we can currently date explicit memory without having to make assumptions that are (at least to some) controversial. However, we find it equally fascinating that Barr et al., and others, have found regular, age-related progress in when deferred imitation will appear: older children need less exposure to the target actions, and seem to remember more about the event sequences. In fact, there are many age-related changes in deferred imitation discussed in Hayne’s and Bauer et al.’s chapters, including length of delay before events are forgotten, speed of encoding, complexity of the events that can be encoded, and resistance to interference (see also Bauer, 2005, for review). For example, while 21-month-old infants shown a 3-step puppet sequence modeled on a cow puppet remembered the sequence when tested with the cow puppet and a duck puppet, 18-month-olds only remembered the sequence with the same puppet from acquisition (Hayne, MacDonald, & Barr, 1997).

Similarly, although infants may succeed in VPC at very young ages, this fact does not imply that their recognition memory does not also develop. We have already seen that generalization changes, and there are other changes as well. For example, Diamond (1990) habituated 4-, 6-, and 9-month-old infants to objects and tested them after delays of 10 s, 15 s, 1 min, and 10 min. Four-month-olds only recognized the objects at delays of 10 s, the 6-month-

olds recognized the objects up to a 1-minute delay, and 9-month-olds recognized objects after intervals as long as 10 minutes.

Documenting the gradual growth as well as the earliest emergence of mnemonic capabilities is a task that requires painstaking and imaginative work, and we are grateful that so much has been done to give us a rich and nuanced view of developmental sequences. What the community of developmental psychologists needs to be careful to do is to maintain awareness of nuance as they make summary statements. Do 6 month old babies “have” explicit memory? Well, yes, but it is very, very fragile. In the real world, it may be only minimally useful. Do one-year-old children “have” explicit memory? Well, yes, and now they have it more robustly and it is more clearly evident to the naked eye. After all, they are poised to begin word learning, one of the greatest memory feats of all. And yet, they may not be accomplished mnemonists—in fact, we know they will soon improve. Faced with facts such as these, Thelen and Smith (1994) abjured the notions of competence or representation altogether. We think that move is unnecessarily radical, but simultaneous awareness of “having” abilities and “having a ways to go” is vital to maintain in describing children.

<1>Where Do Abilities Come From?

Developmental psychology is often described as the study of change over time. Yet it is common to hear unrest concerning whether we are simply *describing* change, rather than tackling the harder task of explaining it. For example, Mark Johnson and Yuko Munakata recently wrote that, “There is general agreement among contemporary researchers that developmental psychology needs to move away from static descriptions of the cognitive system at different ages, and instead strengthen its focus on the underlying mechanisms that generate change.” (Johnson & Munakata, 2005, p. 152). For this volume, Oakes and Bauer asked

contributors to address the question of mechanism directly, and a variety of answers emerged. The explanations in these chapters focus to various extents on explaining memory development in three kinds of ways: by appeals to changes in more basic processes, by citing relevant experiences that can precipitate change, and by considering biological change that might propel behavioral change.

<2> Changes in More Basic Processes

One appealing way to explain developmental change is in terms of underlying advances in basic components of an ability of interest. For example, Rose et al. discuss several mechanisms that might account for developmental change in VPC performance. First, they cite Kail's (1991) suggestion that developments in many cognitive tasks are due to improvements in processing speed. There is evidence to suggest that processing speed plays a central role in performance on VPC tasks. For instance, older infants need less familiarization to recognize targets than younger infants (e.g., Rose, 1980; 1983) and infants take longer to habituate to complex stimuli and show larger novelty preferences when the novel and familiar stimuli are more dissimilar-looking (Caron & Caron, 1969). To examine the role of processing speed in the VPC task more directly, Rose and colleagues designed a procedure that involved a cross between habituation and VPC. Infants of 5-, 7-, and 12-months of age who took more trials to become familiarized showed significantly lower novelty preferences. These data suggest that age-related developments in processing speed play a direct role in infants' performance on the VPC task.

Second, Rose et al. suggest that changes in attention influence infants' VPC performance. Infants can be classified as either "short-lookers" or "long-lookers" depending on the way they divide their attention when examining displays in the VPC. Short-lookers are characterized by short looks, high shift rates (or frequent shifts of gaze), and widely distributed looks. In contrast,

long-lookers are characterized by long looks, few shift rates, and more narrowly distributed looks. There are dramatic age-related developments in infants' attention during the VPC task with mean looks and peak looks decreasing with age and mean shift rates becoming faster (e.g., Axia, Bonichini, & Benini, 1999; Rose, Feldman, & Jankowski, 2001). In a very nice study, the causal link between attention and VPC was shown by pacing long lookers through a "short looker" approach to familiarization, with concomitant change in memory (Jankowski, Rose & Feldman, 2001).

Finding changes in basic processes is a helpful step in the search for mechanism and explanation. The Rose et al. chapter spends the longest amount of time on this strategy of explanation, but Bauer et al. also discuss changes in encoding, consolidation and storage, locating developmental differences more in the last two processes than in the first. However, there is a regress here, because the next logical step is: Why is there change in basic processes? When processing speeds, attention, consolidation or storage change, they must do so for a reason. Often, in the end, the appeal is to a maturing aspect of the nervous system that creates a change in a basic process, as Bauer et al. do in discussing how changes in consolidation and storage may relate to neural development. More rarely, there is an appeal to aspects of the environment that may create change in basic processes. The training study by Jankowski et al. (2001) is an interesting clue showing what experience can affect in the short term. It would be interesting to push their insights further, thinking about what environmental experiences in the real world might be relevant to aiding infants' encoding ability. What do caretakers do to guide attention, given that they do not carry small flashlights with them routinely?

<2> Experiences That Can Lead to Change

These four chapters contain several interesting observations relevant to how experiences may change and enhance memory. One theme, emphasized by Snyder, is that accumulating semantic knowledge will change memory. A basic tenet of a constructivist approach to memory, which is now tacitly accepted by most of the memory community, is that encoding and retention are enhanced by a cognitive structure that makes sense of experience and allows for fitting experience into schemata or scripts rather than having to retain “raw” information. Another factor that may influence infants’ memory performance is the onset of independent locomotion. Hayne and colleagues have shown that, when infants’ chronological age is held constant, crawling status affects the degree to which infants can remember target actions in new contexts. For example, 9-month-old infant crawlers showed excellent memory in a deferred imitation task even when objects and context were changed. Non-crawlers, however, only showed memory for modeled actions when the objects and context remained unchanged (Gross & Hayne, 2004; Herbert, Gross, & Hayne, 2003). The fact that babies must deal with changing contexts as they crawl may well have created this effect—one’s highchair is the same when viewed from one vantage point, against the backdrop of a window, and when viewed from a different vantage point, against the backdrop of the refrigerator. Yet right now we can only speculate as to how crawling exerts its effect, and as to why crawling does not create mnemonic independence of all context—remember that Robinson and Pascalis (2004) found change in the ability to succeed at VPC with changing backgrounds much later than crawling appears, between 12 and 18 months.

<2>Underlying Biological Change?

These chapters frequently discuss the hippocampus, one of the most important cortical substrates for explicit memory, and frequently assert that portions of the human hippocampus reach maturity in the first 6 months of life. This idea fits well with the favored hypothesis that

explicit memory is present early (Nelson, 1995; Seress, 2001). However, also presented in these chapters are lines of evidence that there is developmental improvement in the robustness of explicit memory. There is reason to believe that the human hippocampus may well develop in various ways over a fairly long period. Seress (2001) distinguishes four periods in development, with the last one occupying the third to the fifth year. He states that “full maturation is not expected to occur before the 5th postnatal year in the human” (p. 56). In a recent review, Bachevalier and Vargha-Khadem (2005) state that, “The available evidence to date suggests that the primate hippocampus appears to mature progressively during the first few years of life in both monkeys and humans.” (p. 171).

An important distinction in explicit memory differentiates semantic and episodic memory. There is some evidence that they have different bases in the medial-temporal system. “[T]he hippocampal circuit provides the necessary processing for the encoding and retrieval of context-rich episodes and events, whereas the perirhinal and entorhinal cortices subserve the formation of context-free cognitive memories.” (Bachevalier & Vargha-Khadem, 2005, p. 172). This suggestion might lead to a promising line of research that would more closely evaluate linkages between various forms of explicit memory and neural development in different medial-temporal lobe structures.

We find it a striking fact that there is evidence from research on the development of spatial memory that suggests that there is pronounced developmental change between 18 and 24 months on tasks that are known to be supported by the hippocampus, such as place learning (Newcombe, Huttenlocher, Drumme & Wiley, 1998) and delayed and relational spatial tasks (Sluzenski, Newcombe & Satlow, 2004). Such behavioral evidence may indicate developmental change in the area of the brain known to also support episodic memory. Is it a coincidence that

the earliest autobiographical memories that will last until adulthood date back only to this time? Perhaps, but we would speculate--perhaps not.

<1>In Conclusion

It was a pleasure to read these chapters. Although we differ with some of their conclusions—and they differ from each other—the most important fact is that we have reached a stage of scientific maturity where we have enough facts that our theorizing and hypothesis testing can be focused, and our differences can be specific rather than doctrinal. For the record, here is what we see as the current state of play. Explicit memory begins early, although we are not sure if “early” means 6 months or even earlier than that. It also changes and develops in very marked and functionally important ways, with perhaps one crucial time being towards the end of the first year when we can speculate that it becomes robust enough to support word learning. However, early explicit memory may be primarily semantic in nature, a fact that may have adaptive value. The capacity for truly episodic memory, involving relations among elements of semantic memory and context sensitivity, may begin to emerge around the second birthday and support the first appearance of autobiographical memory. Development continues through the preschool years and involves changes in the relation of explicit and implicit memory, strategies for evaluating memory, binding elements in episodic memory, and many more dimensions too numerous to name. (For a discussion of some of the social factors we have neglected, see Nelson & Fivush, 2004). By the age of 5 or 6 years, memory systems are functionally mature, although there are changes in the use of strategies such as rehearsal, organization and self-testing (e.g., for recent work in this tradition, Schneider, Kron, Hunnerkopf & Krajewski, 2004). Another 15 years of research of the excellence embodied in this book should tell us how right (or wrong) we are in this thumbnail sketch.

Footnote

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² Bauer et al. define explicit memory in a way we would prefer to reserve for episodic memory, as involving “*what* happened, *where*, *when* and even *why*”.

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