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Analysis of the early development of implicit memory:
Characteristics, course, and implications

Routhieaux, Barbara Curchack, M.A.

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ANALYSIS OF THE EARLY DEVELOPMENT
OF IMPLICIT MEMORY:
CHARACTERISTICS, COURSE, AND IMPLICATIONS

by
Barbara Curchack Routhieaux

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[Signature]  [Date]

Elizabeth L. Glisky
Assistant Professor of Psychology
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ABSTRACT

Several researchers have hypothesized that implicit memory remains stable across the lifespan. Empirical support with children has been difficult to interpret due to methodological weaknesses including baseline variation, floor and ceiling effects, and lack of experimental dissociations. A new measure of repetition priming, the picture fragment completion task, was developed to account for these weaknesses while being appropriate for both children and adults. Adults and children aged 4, 6, and 8 (N=156) completed either the picture fragment completion task or an explicit memory test made from same materials. Subjects of all ages performed equally on the priming test while performance increased with age on the explicit memory test. For all ages, the levels of processing manipulation affected only the explicit memory test. Thus, subjects were not using effortful strategies on the priming test. These results form a solid foundation for studying other developmental issues in implicit memory.
LITERATURE REVIEW

Before the 1960s, most researchers believed that those affected with anterograde amnesia could not learn or remember any new information. Amnesic patients performed poorly on tests of free recall, cued recall, and recognition, all of which require conscious recollection of a specific prior event. Then, in a series of experiments, Warrington and Weiskrantz (1968, 1970, 1974, 1978) systematically demonstrated that amnesic subjects displayed near normal performance on some kinds of memory tests. Although amnesic subjects still performed at severely impaired levels on traditional tests of memory, they performed much like normal subjects on memory tests that did not require conscious recollection of the study event. For example, amnesic subjects were as likely as normal subjects to complete perceptually fragmented words if they recently saw the whole word. They performed much worse than the normal subjects, however, on recall and recognition tests of the same words (Warrington & Weiskrantz, 1970).

Because amnesic patients performed well on some memory tests but not on others, researchers hypothesized that memory is not a unitary construct (e.g. Tulving, 1972; Warrington & Weiskrantz, 1974). Rather, two independent phenomena were needed to explain performance on different memory tests. One phenomenon was revealed on tests that required subjects to process information without consciously thinking back to prior occurrences. On these tests, intact memory facilitated processing of a stimulus that was previously presented. This facilitation in processing
was referred to as "priming." The other form of memory, recollection, was revealed on tests that required the subject to consciously recollect the episode in which the material was studied.

Theories Explaining Priming

Findings of preserved memory in amnesic subjects led researchers to hypothesize that normal memory may be characterized by at least two dissociable phenomena. Researchers formulated three major theoretical explanations to account for differential performance on tests of priming and recollection: activation, transfer appropriate processing, and multiple memory systems. The activation hypothesis, an offshoot of the dual process theory of recognition proposed by Mandler (1980, 1989, 1990; Graf, Mandler, & Haden, 1982; Graf & Mandler, 1984), suggests that when a stimulus is presented, two processes occur, integration and elaboration. Integration is phenomenologically known as the feeling that a stimulus is familiar. This integration refers to the automatic activation of the stimulus' mental unit. Perceptual contact with a stimulus activates the internal features of that stimulus' mental unit without one's conscious awareness. Integration makes a presented stimulus more readily accessible for use than other non-presented stimuli. Thus, priming may occur as a result of the integration of a stimulus' mental representation. When the process of elaboration occurs, on the other hand, the stimulus' mental unit and its associations

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1. Priming may be measured with many different methods. For a review of the major standard methods of measuring priming, see Schacter (1987).
are reactivated and related to other units, thus strengthening old associations and forming new ones. Elaboration does not strengthen a stimulus' mental unit. Rather it modifies the associations a mental unit has with other mental units. According to Mandler, information must be successfully elaborated if it is to be consciously remembered. If no associations are made with other mental units, there is no mental path to guide conscious retrieval of the unit from memory. According to the activation view, then, patients with amnesia have intact integrative processes, though their elaborative processes are impaired.

The transfer appropriate processing approach, put forth by Roediger and colleagues (e.g. Roediger, Weldon & Challis, 1989), suggests that subjects use processes to transfer information from study to test. The probability of successful performance on a memory test depends upon the similarity between the processes used to encode and retrieve information. Optimal performance on memory tests occurs when the processes used to encode the items overlap with the processes used to retrieve them. As the types of processing become more different between encoding and retrieval, memory for the items decreases.

Roediger et al. (1989) hypothesize that encoding and retrieval processes are not discrete. Rather, they represent points along a processing continuum. At one end of the continuum are data-driven processes, which rely heavily on the structural aspects of an item. At the continuum’s other end lie conceptually-driven processes, which assess the meaning of an item and its relations with other items. Subjects
usually utilize data-driven processes on priming tasks, while they use conceptually-driven processes on recall and recognition tasks. It is important to note, however, that some priming test require conceptually-driven processing. Likewise, some tests of recollection require data-driven processing (e.g. Blaxton, 1985, in Roediger et al., 1989; Weldon & Roediger, 1987, in Roediger et al., 1989). Also, because these processes are the endpoints of a continuum, processes lying in between may account for performance on some memory tests.

Theoretical arguments proposing that memory is composed of multiple systems have come from many camps (e.g. Cohen & Squire, 1980; Squire & Cohen, 1984; Graf & Schacter, 1985; Mishkin, Malamut, & Bachevalier, 1985; Tulving, 1985). These researchers assume that if a person acquires a deficit following brain injury, the locus of the brain injury is associated with a damaged system (e.g. Tulving, 1983). They propose that amnesic patients’ curious performance on memory tests is due to an intact memory system modulating priming, with a damaged system no longer effectively modulating recollection. Researchers generalize their findings to normal subjects because logic dictates that if brain injured people have these two systems, uninjured people also have them.

Cohen and Squire (1980, Squire & Cohen, 1984) postulate one of two major systems approaches that explain intact memory abilities of people with amnesia. According to their view, memory is divided into two such systems, the procedural memory system and the declarative memory system. Different brain loci are
responsible for processing within these systems. According to Squire (1987), when a stimulus activates the procedural memory system, relationships among brain structures within that system change in an "on-line" fashion, thus fine tuning the system for further encounters with that stimulus. The procedural memory system works without conscious awareness, thus accounting for classical conditioning, motor skill learning, and priming effects. Squire suggests that the procedural memory system is intact in amnesic patients. Thus, activation of the procedural memory system accounts for amnesic patients' ability to acquire new skills, such as computer programming and data entry (Glisky & Schacter, 1987, 1988; Glisky, Schacter & Tulving, 1986), and maze learning (Corkin, 1965).

Squire and Cohen (1984) suggest that if information is to be consciously remembered, the declarative memory system must be activated. The declarative memory system creates, organizes, and utilizes a code, or record, that mentally represents stimuli in the environment for subsequent conscious recollection. Amnesic patients have an impaired declarative memory system; their record of new facts and life experiences after the onset of their amnesia is damaged. Researchers believe the declarative memory system utilizes brain areas within or connecting to the medial temporal lobes, because amnesic patients invariably have damage to this area of the brain.

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2Squire and Cohen use "activation" differently than Mandler and his colleagues. According to Squire and Cohen, activation refers to "turning on" a system. According to Mandler, it refers to the activation of a mental unit or representation.
brain (Scoville & Milner, 1957; Warrington & Weiskrantz, 1978). According to Cohen and Squire (1980, Squire & Cohen, 1984), amnesic patients can, therefore, learn new skills and be affected by previous events, but they cannot recollect facts and events of their lives that occur after the injury.

Graf and Schacter (1985) propose a third explanation of amnesic patients' intact priming but impaired recollection. According to these researchers, the extent to which conscious thought is involved determines the type of memory system being utilized on a memory test. Subjects use the explicit memory system when they are required to consciously think back to information presented at study. Recognition and recall tests, on which amnesic subjects perform poorly, measure explicit memory. On the other hand, subjects use the implicit memory system, when performance on a test is not mediated by conscious referral back to the study situation. That is, the prior presentation of a stimulus facilitates performance without the subject consciously thinking back to it. Priming tests measure implicit memory, because subjects are, by definition, unaware that their memory is being tested. Amnesic patients, according to these researchers, have intact implicit memory, because they show intact priming. Their explicit memory, however, is impaired.

As will be seen shortly, the experiment put forth in this proposal attempts to characterize developmental trends in priming. The theories accounting for priming are not being tested here. On both priming and implicit memory tests, unconscious retrieval of a studied stimulus facilitates the processing of that stimulus relative to an
unstudied one. For this reason, a systems account will be assumed, with implicit memory as the proposed system accounting for priming, and explicit memory as the proposed system accounting for recollection.

**Independence of Implicit and Explicit Memory**

It has already been shown that implicit and explicit memory dissociate in amnesic patients. More recently, researchers have attempted to dissociate the two memory systems in normal subjects (e.g., Graf, Mandler & Haden, 1982). Researchers have now dissociated implicit and explicit memory in normal subjects in three ways. First, investigators have observed differential effects of the same experimental manipulation on tests of priming and recollection (e.g. Jacoby & Dallas, 1981; Roediger & Blaxton, 1987). Second, they have shown that results of priming and recollection tests are statistically independent (e.g. Tulving, Schacter & Stark, 1982). Finally, and most recently, they have observed developmental differences between tests measuring each phenomenon (e.g. Light & Singh, 1987).

When researchers try to characterize implicit memory and explicit memory in normal subjects, it is necessary to have some proof of dissociation between the two systems (Schacter, Bowers & Booker, 1989). If no measure of dissociation is present in an experimental design, there is no way to tell if subjects are consciously thinking back on tests designed to measure implicit memory. Therefore, Schacter et al. (1989) proposed the "retrieval intentionality criterion" to ensure that subjects do not voluntarily or intentionally use explicit memory on an implicit memory test. The
criterion has two requirements: (a) the use of an experimental manipulation (discussed below) that produces differential effects on the implicit and explicit memory tests, and (b) the use of identical materials for both tests, such that the tests are identical except for variations in instructions. Schacter et al. suggest that all tests measuring implicit and explicit memory in normal subjects should follow the retrieval intentionality criterion.

**Experimental Manipulation**

If one wants to demonstrate that performance on two tests reflects the operation of two independent phenomena, one may show that the two behave differently when subjected to the same experimental manipulation (Tulving, 1983). In one of the first studies of priming in normal subjects, Jacoby and Dallas (1981) demonstrated that priming and recollection were independent by showing that an encoding manipulation affected priming and recognition tests differently. These authors manipulated the ways that subjects encoded the items and observed the outcome on tests of priming explicit recollection. Previous studies (Craik & Tulving, 1975) had demonstrated that the deeper or more meaningfully a subject encoded an item, the greater the probability of recollecting that item later.

The goal of the Jacoby & Dallas experiment was to determine if level of processing during encoding differentially affected recognition and priming test performance. For each study word, subjects answered a question requiring elaboration, judgement of phonemic quality, or examination of the letters of the word.
Subjects then completed a recognition memory test, measuring recollection, or a perceptual identification test, measuring priming. As is the case with most perceptual identification tests, subjects saw studied and novel words presented very briefly (less than one second) and then tried to identify them. Priming was detected if the subject had a greater chance of identifying studied words than novel words.

Jacoby and Dallas (1981) found that the level of encoding had no effect on priming, although it affected recognition performance. Words encoded meaningfully were recognized more often than words encoded phonemically, which in turn were recognized more often than words encoded structurally. On the perceptual identification test, studied words were identified at higher rates than novel words (baseline), but the rate of priming over baseline was the same regardless of level of encoding. Because this finding has been well replicated, many experimental paradigms now include a levels of processing manipulation when implicit memory and explicit memory are compared in normal subjects (e.g., Graf & Mandler, 1984; Carroll, Byrne & Kirsner, 1985; Graf & Schacter, 1985; Jacoby, 1983; Schacter & Graf, 1986; Tulving et al., 1982). When level of encoding affects recollection but not priming, researchers can conclude that subjects are not using explicit memory on an implicit memory test.

When researchers manipulate the structural features of studied items, they also observe differential effects on implicit and explicit memory tests. Explored manipulations include changing the appearance of the items between study and test
(e.g., changing typeface between study and test, Roediger & Blaxton, 1987), shifting sensory modality such that information presented auditorily is tested visually (e.g., Graf, Shimamura & Squire, 1985), and studying items as words but then testing them as pictures (or vice-versa) (e.g., Weldon & Roediger, 1987, in Roediger et al., 1989).

For example, Jacoby & Dallas (1981, experiment 6) tested the effects of shifting sensory modality between study and test. First, words were presented either in the auditory or visual modality. A visual perceptual identification test was then given. Results indicated that priming only occurred when study and test were given in the same modality. Visual priming thus seemed to be modality specific. Recognition performance, however, was unaffected by the modality of presentation. Therefore, implicit and explicit memory were dissociated, because shifting modality affected one test but not the other. This finding has been replicated in other studies (e.g., Clarke & Morton, 1983).

Contrary to earlier results, other researchers (Graf, Shimamura & Squire, 1985; Roediger & Blaxton, 1987) have found priming across sensory modalities, but at reduced levels relative to same-modality priming. Take, for example, an experiment conducted by Roediger and Blaxton (1987). Subjects visually studied some words and made judgements about others after hearing them. Priming was measured by the word fragment completion method (developed by Tulving et al., 1982). In the priming condition, subjects tried to complete fragments of studied and novel words that had only one possible correct completion, such as A  A  I N.
for ASSASSIN. Priming was detected if the probability of completing fragments of studied words was greater than the probability of completing fragments of novel words. Priming performance was compared with standard yes/no recognition performance. As expected, the consistency of modality between study and test did not affect recognition performance. Contrary to Jacoby and Dallas' results (1981), however, priming occurred regardless of presentation modality, but the magnitude of priming was greatest when study and test depended upon the same modality. Thus, although the researchers found priming across modalities, it was reduced relative to priming with in the same modality. Recognition, on the other hand, was unaffected by modality of presentation. Therefore, implicit and explicit memory may also be experimentally dissociated on the basis of presentation modality.

Stochastic Independence

Researchers have also statistically dissociated implicit memory and explicit memory (e.g., Graf & Schacter, 1985; Perruchet & Baveaux, 1989; Tulving, et al., 1982; Witherspoon & Moscovitch, 1989). Stochastic independence is achieved if the probability of performing well on items on test A is unrelated to the level of performance on the same items on test B.

Some researchers have questioned the validity of using statistical procedures to suggest independence between systems. For example, Shimamura (1985) warned that intertest biases may confound results when both types of memory are measured in the same testing situation. Successfully completing an item on the first test may influence
the probability of that item being correct on the second test. Data from Tulving et al. (1982) serve as an example of how the order of tests can dramatically affect stochastic independence. When the priming test preceded the recognition test, successful priming of an item increased the probability of recognizing it on the subsequent recognition test. Thus, when a priming test was given first, the two tests were statistically dependent. On the other hand, Tulving et al. found that if the recognition test preceded the priming test, successful priming of an item was unrelated to the probability of correctly or incorrectly recognizing it.

Shimamura argued that Tulving et al.'s finding of stochastic independence did not necessarily imply that priming and recognition reflected two independent memory systems. First, completing a recognition test between encoding and the priming test significantly affected priming performance. Although Tulving et al. found stochastic independence when recognition preceded priming, mean priming was significantly higher when the recognition test was given first rather than second (.65 versus .46). Merely presenting the items in a recognition format increased the probability of items being primed. Therefore, the true degree of dependence between tests is unclear. Shimamura showed that a small "test priming" bias, such that successfully recognizing an item increased the probability of successful priming 30% of the time, could have made the Tulving et al. finding of stochastic independence a spurious one. Shimamura statistically showed that a small test priming effect could mask a large dependence between performance on two tests.
Shimamura did not suggest that a strong dependence between the tests existed in Tulving et al.'s experiment. He did, however, warn that researchers must consider and pay attention to such test biases in order to avoid spurious results. Further, Shimamura suggested that test biases may not occur if the two tests require different types of responses (i.e. yes/no vs. production of the studied item). Thus, with careful monitoring and awareness of possible test biases, stochastic independence can be a useful measure of the relationship between two systems.

**Developmental Evidence: Functional Independence**

Functional independence between two phenomena exists when a population is systematically impaired on one task while unimpaired on the other. Functional independence is different from experimental independence, in that experimental independence involves manipulation of a testing situation, while functional independence is achieved simply because of organismic differences in the individuals. Thus, the first dissociations between priming and recollection were functional in nature, because, as mentioned above, amnesic patients performed well on priming tests but not on tests requiring conscious recollection.

Preserved learning in amnesic patients has led researchers to try to identify other functional dissociations between implicit and explicit memory. For example, it is now widely believed that normal elderly have deficits in explicit memory with relatively spared implicit memory (for reviews, see Albert, 1988 or Hultsch & Dixon, 1990). Thus, as adults age, explicit memory declines while implicit memory appears
to remain stable (Chiarello & Hoyer, 1988; Howard, Heisey & Shaw, 1986; Light & Singh, 1987; Rabinowitz, 1986). Other researchers have found that implicit memory degenerates in adults who are aging pathologically (Bondi & Kaszniak, 1991; Butters et al., 1988; Heindel et al., 1989). These findings are especially important, because researchers may identify the neural substrates responsible for affected memory systems by correlating affected areas of patients' brains with the types of memory that fail.

Compared to the plethora of research examining adult aging and implicit memory, very little research has been aimed towards understanding how implicit memory manifests itself during early development. Studying early implicit and explicit memory development may provide insights concerning other research issues in memory. For example, priming may or may not show the same modality specificity in children as it does in adults. Children with Down Syndrome have deficits in explicit memory (e.g. Lorsbach & Gray, 1985), especially for information presented to the auditory system (Bilovsky & Share, 1965; Rohr & Burr, 1978). An interesting area of research concerns whether or not auditory implicit memory would be impaired relative to visual implicit memory in this population.

So far, a handful of researchers have attempted to characterize implicit memory development (e.g. Carroll et al., 1985; Naito, 1990; Graf, 1990). However, this new research has been victim to unique methodological problems. The purpose of this thesis is to (a) review the developmental literature regarding implicit memory,
(b) address the major methodological issues faced in studying implicit memory development, and (c) describe an experiment that provides a foundation upon which to build a research program studying implicit and explicit memory development.

**Nature of the Developmental Course.**

Several researchers have proposed that children are born with intact implicit memory but that their explicit memory develops over time (Graf, 1990; Rovee-Collier, 1991). Schacter & Moscovitch (1984) suggested that an early memory system, like implicit memory, is intact in infancy, while a late memory system, like explicit memory, develops throughout childhood. Although this theory makes sense on an intuitive level, it has not yet been adequately verified by empirical data. At the present time, only five attempts have been made to directly characterize implicit memory development in relation to explicit memory. These attempts are reviewed below.

Carroll, Byrne, and Kirsner (1985) first tried to dissociate and characterize the course of implicit memory in children. They chose pictures as stimuli so that children younger than reading age could participate. Two experiments were conducted. In the first experiment, children aged five, seven and ten \((n=42\) each) viewed 25 Snodgrass and Vanderwart (1980) pictures. One half of the children encoded the pictures shallowly by reporting whether or not a small cross had been put in the picture. The other half encoded the information deeply by deciding if the object in the picture could be picked up and carried easily. Subjects were not told
that the study would be followed by a memory test. Implicit memory was tested in 26 children, thirteen who encoded shallowly, and thirteen who encoded deeply, by asking them to name the 25 old pictures and 25 new pictures as fast as they could. Difference in naming latencies between old and new pictures was the measure of implicit memory. Explicit memory was tested by recognition in the remaining sixteen children, half of whom encoded shallowly, and half of whom encoded deeply. Children saw the same 50 pictures and responded as quickly as they could, "Yes," if they had seen each picture before and responded, "No," if they had not.

Because of the consistent findings with older adults, (e.g., Light and Singh, 1987), Carroll et al. (1985) hypothesized that implicit memory, unlike explicit memory, would be unaffected by age and level of encoding. Thus, old items should be named faster than new items, and the priming effect should not differ as a function of age or level of encoding. For the recognition test, Carroll et al. hypothesized that subjects who encoded the pictures deeply should (a) recognize old items more quickly than subjects recognizing old items in the shallow condition and (b) discriminate between old and new items better than subjects who encoded shallowly. Further, recognition performance should improve as subjects got older.

The results of this experiment were confusing, possibly reflecting considerable subject variability, especially among the youngest subjects. For example, an experimenter blind to the type of encoding needed to sit with the five year old children and constantly remind them to respond as quickly as possible. As expected,
all children showed priming, by naming the old stimuli faster than the new stimuli. The difference in latency between old and new items was also equivalent across age, giving early indications that implicit memory remains constant throughout development. Contrary to expectations, however, Carroll et al. (1985) found a levels of processing effect for all ages on the implicit memory task, with deep encoders showing greater priming than shallow encoders. Because encoding manipulations affected priming performance for all age groups, it was difficult to interpret the stability of implicit memory across development.

Recognition performance also produced somewhat confusing results. For accuracy, subjects’ mean performance increased with age and deeper levels of processing. In addition, there was no significant interaction between age and levels of processing. However, discrimination (d’) values for all ages averaged across encoding conditions were negative. No explanation of the negative d’ values was presented.

Since both the priming and recognition tasks were related to the level of encoding of the items, it is difficult to interpret these two tasks as tapping different memory systems. It is possible that recognition and perceptual identification access the same system at young ages. Alternatively, the use of response latency as a dependent variable may have produced the spurious results on the priming measure. The variability in response times across ages was dramatically unequal, with younger children responding in extremely different ways. Adding to the confusion was the
negative d’ data, a finding that should indicate extremely poor performance on the recognition test.

Because Carroll et al. (1985) found levels of processing effects for both naming and recognition latency, they conducted a second experiment using a different procedure to try to experimentally dissociate implicit memory and explicit memory. In this experiment, seven year old children encoded items shallowly (n = 14) or deeply (n = 14) by identifying crosses or judging portability of the 25 items used in the first experiment. They then attempted to identify each of the 25 items and 25 distractors under tachistoscopically degraded conditions. This perceptual identification task was followed by a yes/no recognition test using the same 50 items presented in the first experiment. The researchers did not test the youngest children because of their poor attention and great variability during the first experiment.

For the seven year old children, the only significant effect reported was that old items were identified more accurately than new items. The magnitude of priming was the same for both encoding manipulations. They did not present results from the recognition tests, although they concluded that they had successfully dissociated implicit from explicit memory in seven year old children.

Carroll et al. (1985) provided useful information to be utilized in future studies of childhood implicit memory. First, pictures appear to be appropriate stimuli for preliterate children. Second, it is important to choose a task that does not rely on sustained attention or speed when implicit memory is tested in young children. Next,
it appears that a system modulating priming is present in young children. However, the independence of implicit and explicit memory in children, as well as the nature of their relative developmental courses, are still unclear. Child and adult performance were not directly compared. Further, the retrieval intentionality criterion was not adopted, since the implicit and explicit tasks were somewhat different. Thus, these experiments represent a modest beginning in the study of early implicit memory, but many questions still remain to be answered.

Parkin and Streete (1988) were the next to study implicit memory development from childhood through adulthood. They employed the savings on relearning procedure (e.g. Nelson, 1978; Gollin, 1960) to measure implicit memory in adults and children aged three, five, and seven (n=24 each group). Like Carroll et al. (1985), they used pictures of everyday objects created by Snodgrass and Vanderwart (1980). The pictures were fragmented (Snodgrass, Smith, Feenan, & Corwin, 1987) into eight levels, the first being most degraded and the eighth complete. In the original learning procedure, subjects saw fragment sets for 15 objects. For each object, subjects saw progressively more complete representations until they either correctly identified the object or saw it in its complete form, whichever came first. If subjects identified an object while it was still fragmented, they were shown the complete representation. If subjects could not identify an object even if it was complete, they were told the name of the object, and it was kept as an item for subsequent testing and analysis.
Subjects were tested either one hour or two weeks after original learning. The original fifteen pictures were presented along with fifteen distractors in the same way as at study, starting with the most degraded representation of each object and presenting more complete representations of the object until correct identification was made. The explicit memory task was given simultaneously with the implicit memory task, such that after the subject identified each object, the experimenter asked whether or not it had been an item from the original learning set. Implicit memory was measured by savings, the difference in identification levels for each object between study and test. Recognition discrimination level (d') was used as the measure of explicit memory.

Data collected at the one hour delay could not be used due to ceiling effects in recognition performance (d') for all ages. The seven year old children and adults still exhibited ceiling effects at the two week interval (Respectively, Hits = .91, .98; False Positives = .06, .06), but d' was calculated and analyzed for all groups.

Contradictory to expectations, Parkin and Streete (1988) found that, at the two week interval, implicit memory, as measured by savings, increased with age. The experimenters, however, claimed that the increase in savings across age was due to different levels of initial performance. They therefore calculated a proportional savings score, in which savings was expressed as a proportion of initial level of performance. When they analyzed these proportional savings scores, the age effects disappeared. Analysis of d' revealed that the three year old children showed
significantly poorer recognition than the older age groups, who did not differ from each other. Correlations for each subject between proportional savings and d’ were essentially zero. However, the findings utilizing d’ are difficult to interpret, because of ceiling effects.

Parkin and Streete attempted to account for some of the problems raised by Carroll et al.’s (1985) work. For example, they directly compared the performance of children and adults. There were, however, a number of methodological shortcomings with the savings on relearning paradigm. First, the experimenters measured priming of both novel and familiar stimuli, because some children could not identify some of the objects at study. Next, they changed the original Snodgrass methodology by showing all subjects the complete objects after identifying them in fragmented form (e.g. Snodgrass & Suprenant, 1989). Also, an experimental manipulation that could differentially affect the two memory systems, such as levels of processing, was not included. Finally, their measures of implicit and explicit memory relied upon different test materials, which violated the retrieval intentionality criterion.

It is difficult to draw conclusions from this experiment, because of two statistical limitations. The first concerns the fact that different conclusions were reached depending on whether raw or proportional data were analyzed. Analysis of proportional rather than raw scores was necessary, because the various age groups had differences in baseline performance. If baseline performance could be equated
across age, the two analyses would have yielded identical results and would be more straightforward. The second statistical limitation concerns the interpretation of data that show ceiling effects. None of the data collected at one hour could be analyzed, because recognition performance was at ceiling regardless of age. Even though the two oldest groups still performed at ceiling after two weeks, their data were still analyzed. Because of the ceiling effects, however, the lack of difference in recognition performance among the three oldest age groups is not meaningful. Adding more stimuli to the task may make it more difficult for the older age groups, thereby eliminating ceiling effects.

A few cautious conclusions may be made based upon Parkin and Streete's study. Most importantly, the savings on relearning paradigm appears not to be a good framework to study the development of implicit memory. It is too difficult to control for initial performance levels across age. Also, the savings paradigm currently has no similar task to measure explicit memory. Finally, when comparing adults with children, researchers may have difficulty getting an adequate range of performance on all tasks. Thus, one must carefully choose the methodological paradigm, task difficulty, and statistical procedures when characterizing implicit memory development.

In the next major attempt to characterize implicit memory development, Greenbaum and Graf (1989) designed a methodology suitable for very young children. To encode information, children aged three, four, and five (n = 12 each group) saw
6 pictures from one of four categories and were asked to name and remember them. The 24 pictures making up the four category lists were chosen because they were named by children with intermediate frequency during piloting. During study, all children accurately named the six pictures they saw. Then the children listened to two stories, each ending with a question asking the children to generate words from a category. The first story (baseline) asked the children to generate words from one of the three non-studied categories. The second story (experimental) prompted children to generate words from the category of the pictures they studied. Priming was measured by the difference between the number of items generated from the studied list and the number of items generated from the non-studied list. Both raw and proportional difference scores were calculated with the priming data. Explicit memory was tested immediately following the word generation stories. Explicit memory was measured by presenting the studied pictures face down and asking the children to remember what they were. The experimenters predicted that implicit memory would be stable across ages, while explicit memory would increase with age.

The results of this experiment are much stronger than those of the two previous attempts to understand implicit memory development. First, regardless of whether or not raw or proportional scores were used, priming occurred across all ages, with equal differences between the experimental and baseline stories for all ages. Thus, priming appeared to be stable across ages three through five. As
predicted, the only significant effect for the explicit task was age, with performance increasing with age.

At first glance, this experiment seems to yield strong evidence that implicit memory is stable and explicit memory increases during childhood. There were, however, some unaddressed issues in this procedure as well. First, it is unclear whether or not performance on the two tasks reflected the operation of different memory systems, because there was no experimental manipulation to dissociate them. Second, the researchers could have chosen similar materials measuring implicit and explicit memory. For example, a cued recall test could have been added by including a line such as, "Recently, you saw and named the things found in the kitchen. Tell me all the things you remember seeing earlier that you could find in the kitchen." Also, adults and children were not directly compared, so it is plausible that implicit memory develops in a stepwise fashion, and eight-year-olds may do better than five-year-olds per se. In summary, these findings suggest that implicit memory probably exists in early childhood, but the exact nature of the developmental course of implicit memory is still undetermined.

Next, Lorsbach and Worman (1989) compared performance of learning disabled and nondisabled third and sixth graders. All subjects (N=60) saw progressively more complete fragments of 33 objects until they could name them, and were then tested by free recall, cued recall and savings on relearning, in that order. Contrary to Parkin & Streete's methodology, raw savings (average trials to complete
novel pictures minus average trials to complete previously seen pictures) was used rather than proportional savings. A total of eight objects, with four from the study list, were used in the savings test.

Results indicated that as age increased, free recall and cued recall performance increased. Further, the nondisabled group performed the recall tasks significantly better than the learning disabled group. Interestingly, all subjects performed equally regardless of age or disability on the savings task. These results suggest that in children with learning disabilities, explicit memory may be impaired, but implicit memory is intact and stable between the third and sixth grades. It is unlikely that subjects used explicit strategies on the savings test, because savings was equivalent for all groups, even though they completed the savings test after the recall tests.

Lorsbach and Worman’s results are quite promising, even though they did not directly compare children to adults. It must be noted, in addition, that the savings on relearning paradigm has its own intrinsic flaws, which have been discussed earlier. Further, Lorsbach and Worman concluded that implicit memory is developmentally stable by using raw savings, which increased with age in Parkin and Streete’s experiment.

The most recent attempt to characterize implicit memory development was conducted by Naito (1990). Naito used the fragment completion task, in which the subjects were asked to complete a word fragment that had only one correct completion. Interestingly, this work took place in Japan, so the words were written
in Japanese Hiragana letters. Words contained between four and six letters. Twenty-four six, eight, eleven and twenty-two year old people (N=96) participated in the word completion task. Each age group encoded half of the words (16 words) in a structural way by noting whether or not a letter was present in the word. The other 16 words were encoded deeply by choosing the category from which the word came. Children were tested in groups by having them write down their answers in booklets, so all stimuli were presented in the same order. After the 32 words were shown, subjects completed mazes for 4 minutes. They then attempted a word fragment completion task, in which they wrote down the correct completion of fragments of the 32 old words and sixteen new words.

Results of the word fragment completion task revealed similar patterns as seen in the past. Adults completed more word fragments than children, but all children performed equally. When the numbers of old items correctly completed was subtracted from new items completed, savings scores were equal across ages, indicating developmental stability in priming. Again, baselines were different across ages, and in this case, because the magnitude of priming was equal across age, no proportional scores were derived. As expected, level of processing had no effect on priming performance.

Explicit memory performance was measured in a separate experiment with different subjects. Again, adults and children aged 6, 8, and 11 participated, though the sample sizes were smaller (n’s each group = 24, 28, 22, 17 respectively).
Subjects studied the same 32 words with the same encoding manipulations as those in the priming experiment. They completed the 4 minute distractor maze, and then completed a free recall task by writing down as many of the items they remembered seeing.

Results of the free recall condition indicated that the proportion of items remembered improved as age increased. Further, the effects of levels of processing interacted with age. As age increased, deep (D) encoding became progressively more effective than shallow (S) encoding. Thus, there was no levels effect with the six year old children (D = .05; S = .05), the eight and eleven year olds showed equal levels effects (D = .21, .22; S = .08, .07 respectively), and the adults showed the most dramatic levels of processing effects (D = .32, S = .12). This finding is interesting and replicates an early levels of processing study with children (Lindberg, 1980). However, 18 of the eighty subjects, including seven of the 18 six-year-old children, failed to recall anything on either or both encoding manipulations. Thus, it is difficult to determine whether or not the levels of processing effect exists in young children. These floor effects place a damper on otherwise positive findings. The floor effects observed may have been avoided if cued recall, the type of explicit memory procedure called for by retrieval intentionality, was used.

In a third experiment, Naito (1990) explored how long information stays intact in the implicit memory system in seven-year olds, 12-year-olds, and college age students (n's = 53, 87, and 57, respectively). Without manipulating the level of
encoding, he used the same fragment completion paradigm with half of the subjects. The other half received a recognition test on which the subject saw equal numbers of studied words and distractors, and marked which ones were previously presented. Subjects were tested at both seven minutes or six days after encoding. Naito made no predictions with respect to priming, although he expected that explicit memory would decrease over time.

Analyses for priming and recognition were completed separately, so it is difficult to directly compare the two memory systems. Analysis of hits, true negatives and discriminability (d’) for the recognition task revealed that all subjects performed better at seven minutes than at six days (In order of decreasing age, d’ = 2.65, 2.19, and 2.06 at seven minutes; d’ = 1.13, 1.22 and 1.05 at six days). At seven minutes the adults had more hits and greater discriminability than the children, who performed equally. Analysis of discriminability at six days revealed that all age groups performed equally.

Contrary to expectation, at six days, although all ages had equivalent d’ scores, the adults had fewer hits than the children, who performed equally. Naito explained that the words on the study list might have been more familiar to the adults than to the children, and that this familiarity with the items made identification of hits more difficult for the adults than the children. If this logic concerning familiarity is followed, however, it is unclear why the adults had significantly more hits than the children at seven minutes.
Naito reported few results analyzing the word completion priming task over time. First, previously-seen fragments were completed more often than novel fragments, overall. Next, eleven year olds and college age students completed more words than seven year olds, overall. Finally, performance at six days was greater than at seven minutes when collapsing across age. He attributed this unexpected increase over time to practice effects. Naito did not directly compare the performance of different age groups with each other, and no standard deviations were presented to complete the analysis for oneself. However, if one subtracts the proportion of novel fragments completed from the proportion of repeated fragments completed, the difference looks essentially the same across age, with amount of priming decreasing as the interval between study and test increase (See Table 1). Priming thus appears to remain constant across age.

Many methodological lessons can be learned from the four attempts to characterize implicit memory. An experimental method for dissociating the two types of memory, such as the levels of processing manipulation, should be used to ensure measurement of two distinct systems. An experiment designed to measure developmental trends should include both child and adult groups for comparison. Pictures should be used when testing young children, though the savings on relearning procedure is not appropriate. The best explicit memory task to use for developmental studies may be cued recall, since recognition often shows ceiling effects, and free recall can produce floor effects. Rather than manipulate data to account for initial
performance after the data has been collected, one should attempt to equate baselines for the different ages. This will allow for more straightforward explanations of performance, because raw and proportional data should reveal equivalent results. Thus, while experimenters are still unsure of the exact nature of implicit memory development in children, they have avenues to pursue in future studies.

Table 1: Difference in Proportion of Repeated and Novel Word Fragments Identified as a Function of Age and Retention Interval

<table>
<thead>
<tr>
<th>Age</th>
<th>Retention Interval</th>
<th>7</th>
<th>12</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Minutes</td>
<td>.22</td>
<td>.27</td>
<td>.21</td>
<td></td>
</tr>
<tr>
<td>6 Days</td>
<td>.17</td>
<td>.19</td>
<td>.16</td>
<td></td>
</tr>
</tbody>
</table>

Note. Proportions are calculated from graphs presented in Naito (1990).
Summary

The study of priming has progressed rapidly since it was first systematically studied in amnesic patients. There are competing hypotheses attempting to explain the dissociation between priming and recollection. One of the major theories proposes that memory is made up of two systems. The explicit memory system facilitates conscious recollection of learning episodes. The implicit memory system facilitates processing of an item after it has been processed once. This facilitation occurs without the subject's conscious utilization of its prior occurrence. Researchers dissociate implicit and explicit memory in normal subjects in three primary ways. Experimental dissociations are obtained when encoding manipulations produce differential performance on two tests. Statistical dissociations are obtained when the probability of producing an item on an implicit memory test is unrelated to the probability of producing that item on an explicit test. Functional dissociations are obtained when the two kinds of memory tests are related to subject variables, such as age.

I propose to compare implicit and explicit memory in children and adults using a new priming paradigm attempting to equate baseline performance across age groups. The experiment will operationalize implicit memory as performance on a picture fragment completion task. In this task, fragments of objects rather than words will be used as stimuli so that priming may be measured in preliterate children. Baseline identification levels of the picture fragments will be determined during a pilot study,
and different fragments of the same objects will be used for the different age groups. This procedure will allow average baseline completion performance to be equated across ages. Making the tests equivalent for identification difficulty will eliminate the need for post-hoc manipulation of the data. Priming will be measured as the number of studied items identified minus the number of novel items identified. On the task which operationalizes explicit memory, a cued recognition task, the subject will decide whether the same fragment is part of one of the previously presented objects. Explicit memory will be measured as the difference between hits and false alarms on this task.

The following experiment will attempt to dissociate implicit and explicit memory in three ways. First, it will utilize a levels of processing manipulation to obtain an experimental dissociation. In addition, the same cues will be used for the implicit and explicit tests thus satisfying the retrieval intentionality criterion. Second, to get a developmental picture (and a possible functional dissociation), children who are approximately four, six, and eight years old as well as a college age group will be participate. These ages will participate, because researchers believe four year olds do not use explicit strategies on tests of recollection, eight year olds use strategies spontaneously, and six year olds are in a transitional phase during which they can be taught the strategies but do not use them spontaneously (e.g. Bray, Justice & Zahm, 1983; Justice, 1985; Kobasigawa, 1984). A group of college age students will be added in order to understand developmental trends occurring after the
age of eight. Finally, statistical procedures will be used to assess stochastic independence, in an attempt to replicate Tulving et al.'s (1982) findings in a word fragment completion.

PILOT STUDY

Method

Subjects

A total of 84 subjects participated in a pilot study. Twenty students at the University of Arizona volunteered as a way to fulfill a course requirement. In addition, 24 4-year-olds, 20 6-year-olds and 20 8-year-olds attending private schools in Tucson, Arizona and surrounding suburbs comprised the child groups. Children had to meet the following two criteria: (a) their birthdays were within three months of one of the age groups, and (b) their parents gave informed consent. Six- and 8-year-old children also signed abbreviated consent forms. Any subject with a reported history of learning disability or neurological impairment was not included in the study.

Materials

Seventy-nine sets of fragmented pictures (Snodgrass & Corwin, 1988; Snodgrass, 1990) thought to be identifiable by 4 year olds, according to Carroll and White (1973), were used. Each set consisted of eight levels of fragmentation, with level 1 being most fragmented and level 8 being complete.
Procedure

Phase One: College Students. Twenty subjects (10 males, 10 females) were tested individually in one 75 min session, in a room free from distractions. Subjects saw each set of pictures in order of increasing completeness, and identified the object as soon as they could. Subjects were not penalized for incorrectly identifying the objects. For the complete set of instructions, see Appendix A.

The experimenter generated four random orders of presentation, which were counterbalanced across subjects. For each set, the experimenter presented the most fragmented level of the picture first, and stated, "What do you think this is?" The experimenter then presented more and more complete representations of the object until the subject correctly identified it by an acceptable name. Subjects were encouraged to put effort into their responses, but reinforcement was not given solely for correct identifications (e.g., "Keep trying", "Here's a little bit more," "Keep thinking," or "How about now?"). Five minute rest periods were provided if needed after presentation of the 20th, 40th, and 60th items. All of the subjects' responses were recorded on a coding form.

Phase Two: Four Year Olds. Testing for this group took place individually, over a period of four to five 15 - 20 min sessions in a room free from distractions. The experimenter told the children that they would play a "picture naming game." In this game, they would see incomplete pictures of common objects and try to identify them as soon as they could. The experimenter modified the procedure for the 4 year
olds in two ways. First, the experimenter did not present eight of the original 79 object sets to the 4 year olds, because at least one college age subject could not identify the object, even when complete. Second, based on the performance of the college students, the experimenter eliminated some of the most fragmented pictures from the remaining sets. After elimination, the most incomplete representation of each set was one level more fragmented than the level at which any college age subject could identify the object. If a college student identified an object at its most fragmented level, the experimenter did not modify the set. This procedure was adopted to save time, since the young children showed difficulty paying attention in prior experiments (e.g. Carroll et al., 1985).

Pictures were presented until the child participated for 15 minutes or the child tired and wished to return to class, whichever came first. Six children withdrew from the project before completing identification of all object sets. Four additional subjects completed the unfinished sets of the subjects who withdrew, so that 20 subjects identified each object.

**Phase Three: Six and Eight Year Olds.** Only one modification was made to the testing procedure for the four year old children. If one or more 4-year-olds could not identify an object at its complete representation, the experimenter eliminated its set from those presented to the older children. The six and eight year old children then identified the objects in the remaining modified sets at the most incomplete levels they could.
Results

For each age group, the proportion of subjects identifying pictures at each level was calculated. Two lists of 20 common objects were then generated such that the average baseline identification probabilities were equivalent for all age groups, although the actual levels of fragmentation varied within and across age groups. Baseline identification probabilities are presented in Table 2. A 2 X 4 analysis of variance revealed no main effect for list \( F(1, 152) = 0.00, MSe = 153.88, p > .05 \) or age \( F(3, 152) = 0.00, MSe = 153.88, p > .05 \). Thus, overall, both lists of fragmented objects were equally difficult for all ages. The difficulty levels of each individual item from the lists, however, varied across age groups.

To minimize variability, no object included in either list contained average identification proportions below .10 or above .60. Both lists contained equal numbers of objects from the same categories (i.e. animals, modes of transportation, etc.). Further, both lists had equal numbers of "easily liftable" objects, because of portability judgements that are required in the following experiment. Both final lists are presented in Appendix B.
Table 2: **Mean Identification Percentages of Set A and Set B as a Function of Age:**

**Pilot Study and Experiment**

<table>
<thead>
<tr>
<th>Condition</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pilot Study:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set A</td>
<td>M</td>
<td>37.5</td>
<td>37.6</td>
<td>37.7</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(14.9)</td>
<td>(11.2)</td>
<td>(9.4)</td>
</tr>
<tr>
<td>Set B</td>
<td>M</td>
<td>37.6</td>
<td>37.9</td>
<td>37.8</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(14.9)</td>
<td>(13.4)</td>
<td>(9.5)</td>
</tr>
<tr>
<td><strong>Experiment:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set A</td>
<td>M</td>
<td>44.5</td>
<td>49.5</td>
<td>53.5</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(14.2)</td>
<td>(15.7)</td>
<td>(18.6)</td>
</tr>
<tr>
<td>Set B</td>
<td>M</td>
<td>48.9</td>
<td>48.8</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(18.6)</td>
<td>(11.9)</td>
<td>(13.4)</td>
</tr>
</tbody>
</table>
EXPERIMENT

Method

Subjects

Thirty-nine 4-year-olds, 38 6-year-olds, 39 8-year-olds and 40 college students who denied head injury, learning disability and neurological disease participated in this study. Mean ages for the groups were 4.64 (SD = 0.36), 6.05 (SD = 0.38), 8.53 (SD = 0.27), and 21.29 (SD = 5.55), respectively. A prior group of 40 college students were tested, but their baseline identification rates were extremely low, unlike the children's baseline rates, which were somewhat higher in the actual experiment than in the pilot study. The fragmentation was reduced somewhat to raise baseline identification in the adult subjects, which comprised the final group.

Design and Materials

The experimental design consisted of two between-subjects variables: level of encoding (shallow vs. deep) and age (four vs. six vs. eight vs. adult). For purposes of measuring stochastic independence, the type of memory (implicit vs. explicit) was assessed within subjects, with half of the subjects receiving the priming test first and the other half receiving the cued recognition first.

The two sets of 20 Snodgrass and Vanderwart (1980) pictures of common objects chosen in the pilot study are referred to as Set A and Set B. Each picture was placed on a 5" X 8.5" card. The complete objects from either Set A or Set B were presented during study. Four practice pictures were placed at the beginning of the
studied set in order to decrease primacy effects. The other set's fragments were used as distractors during test. During both study and test, all pictures were presented in a fixed semi-random order, such that no two items from the same semantic category were adjacent to each other. To counterbalance, equal numbers of subjects in each age group, type of encoding manipulation and testing situation studied Sets A and B.

In the shallow encoding task, subjects searched for an inked in cross, or "X", written somewhere on the contour of the object. Seven (approximately one third) of the pictures in each set were chosen randomly and marked with a black ball-point pen\(^3\). In the deep encoding task, subjects decided if they could lift and easily carry each object represented in the pictures. These encoding manipulations were the same as those used in Carroll et al. (1985).

The fragments used for the priming and cued recognition tests were presented in the same order, regardless of age. Two fragmented pictures judged identifiable by 95% of all age groups were placed at the beginning of the test to give the subject practice at identifying fragmented pictures. For the children and the first adult group, the fragments selected on the basis of the pilot study were used, such that the 20 fragmented targets and 20 fragmented distractors should have been identified by approximately 37% of subjects in each age group. As mentioned earlier, the final

\(^3\)Fewer than one half of the pictures were marked, because on piloting, subjects searched longer when no X was present. The increase in search time may ensure better structural encoding.
adult group saw more complete fragments than those determined in the pilot study, because of the low baseline performance in the initial adult group.

A filler task between study and test gave the subjects practice at identifying fragmented pictures and decreased the likelihood that subjects in the priming condition would attempt to think back to the study phase when identifying objects. Twenty pictures of letter and number fragments drawn on 5" X 8.5" cards were used for each age group. Adults, eight, and six year old children tried to identify each letter or number from fragments representing approximately 35%, 50%, and 65% of each item, respectively. Because some four year olds did not yet know their numbers and letters, a match to sample test was given for this age group. Four year old subjects matched an 80% complete fragment to its complete representation in the presence of 2 attractive distractors.

Procedure

The experimenter invited each subject to play a "picture game." If subjects gave consent, they were tested individually in a room without distractions. Subjects were told that their memory would be subsequently tested. The experimenter explained that the goal of the experiment was to measure perception and memory. The exact instructions for the two encoding conditions were:

I have a memory experiment to do with you. I am going to show you some pictures of everyday objects on these white cards. When I show you each one, please tell me whether or
not [you see a small cross somewhere in it] [you can pick it up and carry it easily]. Say "Yes" if you [see the cross] [can carry it easily], and say "No" if you [don't see the cross] [can not pick it up and carry it easily]. I will ask you about these pictures later, so try to remember them. Do you have any questions?

These instructions had to be modified for the four year old children, as they often answered that they could lift everything. The experimenter added to the instructions, "There are some things that nobody can pick up, like a truck, while other things everybody can pick up, like a feather. It's Okay if you can't pick up everything. I don't expect you to."

The experimenter presented each picture, including the four practice pictures, to each subject, allowing the subject to study the picture for as long as he or she wished. Immediately after encoding, subjects completed the distractor task, known as a "naming game" to the children, and a "subjective perception" game to the adults. Subjects identified the 20 letter and number fragments appropriate for their age as best as they could. Subjects saw the fragment for a maximum of 5 seconds. Instructions follow:

Now I have a subjective perception experiment to do with you.

I have some more pictures to show you, but this time I'll only show you a little bit of them. If you add all of the lines I took
out, each picture will be either a capital letter or a number. I want you to tell me the first capital letter or number that comes to mind when you see each picture. I'll only show you each picture for 5 seconds, so tell me as quickly as you can. Here's a few examples so you can familiarize yourself with what pictures look like when they're incomplete. This is a "V" [turn], and this is what the "V" looks like incomplete [turn]. This is a "4" [turn], and this is what the "4" looks like incomplete [turn]. This is a "D" [turn], and this is what the "D" looks like incomplete [turn]. Tell me, what letter or number do you think this is [present first item]?

Following the naming game, subjects' memory was tested. Half of the subjects in each encoding condition received the implicit memory test first. The other half received the explicit memory test first. On the implicit memory test, subjects tried to identify incomplete pictures of objects. During piloting of the experimental design, subjects reported noticing that stimuli on the completion test were parts of the studied items. To discourage subjects from thinking back to the studied items, they were told (a) that some of the fragments are parts of studied items, (b) that they should not think back to the study list, and (c) they should say the first item that comes to mind. The test
was speeded, such that subjects had a maximum of 5 seconds to identify each picture. The exact instructions follow:

Now I have a subjective perception experiment. I am going to show you more incomplete pictures, but this time they could be anything. Your job is to tell me what you think each object is. You will only have 5 seconds to look at each picture, so just tell me the first object that comes to mind. Some of the pictures you see are parts of the objects you saw originally, but I do not want you to think back to the original pictures. This is not the memory test, so it is important that you simply tell me the first object that comes to mind. Don’t worry about whether you have seen the object before. [We’ll do the memory test later.] [We already did the memory test.] For now, quickly tell me the first thing that comes to mind when you see each picture.

Ready?

The experimenter elicited responses by asking, "What do you think this is?", each time a fragmented picture was shown until the subject began responding spontaneously. Following the implicit memory test, the experimenter asked the adults whether or not they thought back to the list. Only those subjects who did not report using explicit memory were used for analysis (5 subjects were replaced).
The explicit memory test, a cued recognition test, used the same pictures shown to the implicit memory group. Only the instructions were varied. The experimenter explained to the subject that some of the pictures they would see were fragments of the objects they studied. The subjects were told to think back to the encoding situation and tell the experimenter whether or not the fragment was part of one of the objects they studied. To keep the implicit and explicit tasks similar, the recognition test was also speeded for adults, with subjects having 5 seconds to respond. Only the instructions were varied so as to maintain retrieval intentionality:

Now I have a memory experiment. I am going to show you more incomplete pictures. You should try to think back to when you [looked for the crosses] [decided if you could carry some things] when you answer my questions. Your job is to tell me whether or not the picture is part of one of the objects you saw when you [looked for the crosses] [decided if you could carry some things]. You have 5 seconds to make your decision, and you are to guess if you are unsure. Ready?

The experimenter asked, "Is this part of an object you saw before?" until the subject understood the task and did not need prompting.

After completing the second memory test, the experimenter debriefed the subjects and thanked them for participating. All children were told that
their parents would receive a letter explaining the purpose of the game after all data were collected.

Results

Stochastic independence between the identification and recognition tasks was measured by Chi Squared analysis. Regardless of the order of presentation and age, the completion and recognition tasks were always found to be highly dependent upon each other (p's < .05). All Chi squared analyses ranged from $\chi^2 (1, N = 380) = 19.73$ to $\chi^2 (1, N = 400) = 95.55$. Therefore, the following recognition and priming results reflect performance of different subjects. Only the first test given to each subject was used for the following analysis.

Explicit memory was measured as the difference between hits and false alarms on the cued recognition task. Means and Standard deviations for cued recognition performance are presented in Table 3. A 4 X 2 analysis of variance revealed a significant main effect for encoding $[F(1,71) = 18.65, MSe = 14.40, p < .001]$, with deep encoders performing significantly better on the cued recognition task than shallow encoders. In addition, there was a significant main effect for age $[F(3,71) = 6.85, MSe = 14.40, p < .001]$, with cued recognition performance increasing with age. Linear regression analysis was used to characterize the expected developmental increase in the explicit memory conditions. Subject age (number of days old) was used as the
predictor. Separate regression lines were calculated for the different encoding conditions. Results of the regression analyses are presented in Table 4. Significant linear developmental increases were found for both the shallow [F(1,37) = 10.47, MSe = 21.15, \( p < .01 \)] and deep [F(1,33) = 9.03, MSe = 7.41, \( p < .01 \)] conditions. The age by encoding interaction was not significant [F(3,71) = 0.79, MSe = 14.40, \( p > .05 \)]. Thus there was an overall developmental improvement for this explicit memory task.
Table 3: Cued Recognition (Hits minus False Alarms) as a Function of Age and Encoding Level

<table>
<thead>
<tr>
<th>Condition</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>M</td>
<td>4.40</td>
<td>4.90</td>
<td>6.10</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(3.06)</td>
<td>(2.51)</td>
<td>(3.41)</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Deep</td>
<td>M</td>
<td>7.33</td>
<td>8.50</td>
<td>10.33</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(4.09)</td>
<td>(6.13)</td>
<td>(2.73)</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>5.87</td>
<td>6.70</td>
<td>8.22</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>(3.58)</td>
<td>(4.36)</td>
<td>(3.07)</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>19</td>
<td>20</td>
<td>19</td>
</tr>
</tbody>
</table>

Shallow and Deep conditions.
Table 4: Predicted Developmental Increase of Cued Recognition Performance as a Function of Age and Encoding Type

<table>
<thead>
<tr>
<th></th>
<th>Equation</th>
<th>r</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Encoding</td>
<td>$Y = 0.00076X + 6.46$</td>
<td>0.44</td>
<td>0.19</td>
</tr>
<tr>
<td>Shallow Encoding</td>
<td>$Y = 0.00049X + 3.95$</td>
<td>0.47</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Before results from the priming test were examined, a 2 X 4 ANOVA was conducted to ensure that baseline identification levels were equivalent across age (4, 6, 8, or adult) and list (A or B). Means and standard deviations of baseline identification percentages for both lists are presented in the bottom of Table 2. There were no significant main effects for age \( F(3,69) = 1.78, MSe = 8.41, p > .05. \) or list \( F(1,69) = 0.44, MSe = 8.41, p > .05. \). In addition, there was no interaction between age and list \( F(3,69) = 0.42, MSe = 8.41, p > .05. \). Because list studied did not affect baseline performance in any age group, priming performance was collapsed across list. Thus, priming was measured as the difference between numbers of studied and novel objects that were correctly identified on the priming task. These results are shown in Table 5.

A 4 X 2 ANOVA examined the effects of age and encoding type on priming. As expected, there were no main effects between group means for encoding manipulation \( F(1,69) = 2.02, MSe = 7.77, p > .05. \) or age, \( F(3,69) = 1.13, MSe = 7.77, p > .05. \). In addition, there was no interaction between these variables \( F(3,69) = 0.71, MSe = 7.77, p > .05. \). Thus, statistical analyses confirmed that priming remained constant across age and encoding condition, while cued recognition increased with age and level of processing.
Table 5: **Raw Priming (Test - Baseline) as a Function of Age and Encoding Level**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Age</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>1.80</td>
<td>0.78</td>
<td>3.40</td>
<td>3.10</td>
<td></td>
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<tr>
<td>SD</td>
<td>(2.15)</td>
<td>(2.73)</td>
<td>(1.71)</td>
<td>(2.85)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>3.00</td>
<td>3.11</td>
<td>3.30</td>
<td>3.40</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>(3.50)</td>
<td>(2.98)</td>
<td>(2.91)</td>
<td>(3.16)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>2.40</td>
<td>1.95</td>
<td>3.35</td>
<td>3.25</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>(2.83)</td>
<td>(2.81)</td>
<td>(2.31)</td>
<td>(3.13)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Proportional priming scores, which were obtained by dividing raw priming by baseline identification score, were also calculated. These were used to compare the developmental trends in this study with those of Parkin & Streete (1988), who had nonequivalent baselines across age groups. As expected, no main effects for age \( F(3,69) = 0.30, MSe = 0.22, p > .05 \) or encoding \( F(1,69) = 2.11, MSe = 0.22, p > .05 \) were found. In addition, there was no age by encoding interaction \( F(3,69) = 0.79, MSe = 0.22, p > .05 \). Thus, both raw and proportional priming appeared to remain stable and were unaffected by levels of processing throughout the lifespan.

**DISCUSSION**

Results of the experiment confirmed the hypotheses that explicit memory, as measured by cued recognition, increases with age, while implicit memory, as measured by picture fragment completion, remains developmentally stable. Further, as hypothesized, levels of processing affected cued recognition but not picture fragment completion. The results of the current experiment are consistent with the findings by other researchers who have suggested that implicit memory remains stable throughout childhood while explicit memory improves (e.g., Carroll et al., 1985; Greenbaum & Graf, 1989; Lorsbach & Worman, 1989; Naito, 1990; Parkin & Streete, 1988). In addition, the developmental trend on the cued recognition task was
consistent with past research suggesting gradual improvement across the age groups (e.g., Bray, Justice & Zahm, 1983).

The methodological strength of the current experiment gives further credence to the postulation that explicit but not implicit memory improves throughout childhood. First and most importantly, baselines were equated across ages, eliminating Parkin & Streete’s (1988) dilemma as to whether to use raw or proportional data for analysis. Regardless of whether raw or proportional priming was measured in the present experiment, priming remained stable between ages 4 and adult. Second, the retrieval intentionality criterion was satisfied, such that an experimental manipulation produced different effects on the same materials by varying only the instructions. Next, as can be seen in Table 3, the cued recognition task eliminated the problems of floor and ceiling effects on explicit tasks (e.g., Naito, 1990; Parkin & Streete, 1988). Fourth, the experiment compared adults directly with children of different ages, ruling out the possibility that implicit memory may develop in a stepwise fashion, with children’s performance being equal until a certain developmental milestone and then increasing to a new, stable level (e.g. Greenbaum & Graf, 1989; Lorsbach & Worman, 1989). Finally, no task for the children was dependent upon response time, thus avoiding the inconsistencies on previously observed speeded tasks (e.g., Carroll et al., 1985).
Overall, the cued recognition and picture fragment completion tasks seemed to be good choices for assessing explicit and implicit memory development, respectively. Explicit memory and implicit memory were dissociated both experimentally and functionally, lending credibility to the results. Stochastic independence analysis, however, suggested that successful performance on one task depended upon successful performance on the other. These results contrast Tulving et al.'s (1982) finding of stochastic independence when the recognition test preceded the word completion test. In the present study, the picture completion and cued recognition tasks may have depended upon each other, because they involved similar processes. Recognition of picture fragments as parts of studied objects probably depends upon the ability to identify the object, which is the goal of the implicit task. Thus, both tasks required identification of the objects, leading to dependence. It is unclear whether or not recognition or cued recall tasks would decrease the mutual dependence of the two tasks on identification ability. Even though the measures were not stochastically independent, however, analyses between groups still confirmed all hypotheses.

It is worth noting that although no developmental trend in implicit memory was found, the overall mean priming performance across age groups appeared developmentally unstable. Inspection of Table 5 leads to the conclusion that the developmental instability was largely due to performance of
four and six year old shallow encoders. Performance of the other six priming groups ranged between 3.0 and 3.4, suggesting much more stability in priming.

The low performance of the four and six year olds in the shallow encoding groups is likely an artifact. Nevertheless, a number of possible explanations were considered. First, the possibility that the 4 and 6 year olds in the shallow encoding condition were younger and perhaps failed to understand the nature of the task was examined. However, no age differences were found (Mean age of shallow encoders and deep encoders in the priming condition for the four year olds were 4.78 and 4.59, and for the six year olds were 6.33 and 6.43, respectively.). Second, it was the case that the majority of students in the two shallow encoding conditions came from a school which has a different teaching philosophy than the three other schools from which subjects were selected. How this might have affected the results, however, is unclear. No other individual differences across groups were noticed. Another possibility is that the young children in the shallow encoding condition failed to encode the pictures adequately. If this were the case, however, cued recognition performance for shallow encoders of the same ages should have been lower than was found, as instructions at encoding were identical for all conditions. Finally, it may be that younger children failed to encode the entire pictures when a "X" was present at study as compared to when an "X" was
absent. An item analysis, however, revealed that performance of all subjects on the explicit and implicit tasks was not affected by presence or absence of a cross at encoding. Thus all subjects probably encoded in a similar manner on the shallow encoding task.

It is unlikely that young children in the shallow encoding condition performed worse than their age peers in the deep condition because they were using explicit strategies on the implicit task. First, if young children were using explicit strategies on the implicit test, a developmental increase would be expected in both tests. However, the six year old children performed worse than the four year olds on the implicit task but better than the four year olds on the explicit task. Second, as Table 5 documents, priming performance of all age groups was quite consistent in the deep condition. If the two youngest age groups were using explicit strategies, one would expect to see a developmental trend in deep as well as shallow conditions.

Given the accumulation of evidence supporting lack of developmental trends in implicit memory, it seems likely that these two somewhat low scores are not meaningful.

The pilot study effectively eliminated pictures that were not appropriate for young children. It also provided information as to how difficult the objects were to identify. However, the baseline identification performance in the actual experiment was considerably different than that obtained in the pilot
study. Comparison of baseline scores in Table 2 reveals an increase of about 13% between pilot and test. The first experimental adult group (not presented) was discarded, because their baseline identification rates in the experiment were below 30%. To maintain equivalence across ages in baseline identification rates, a second experimental adult group saw slightly more complete fragments than those used in the pilot study in order to increase the baseline to approximately 50%.

Several possibilities may account for the difference between expected and actual baseline identification performance. First, during piloting, the four and six year olds seemed to perseverate on their responses, repeating the same responses even after being told that they were wrong. Perseveration may have increased identification thresholds and underestimated their ability. Second, the adults in the pilot study may have been able to make use of feedback from early fragments to enhance their identification of later fragments. This may have led to an overestimation of baseline performance in the pilot study, and poorer baseline identification during the experiment. Third, the distractor identification task could have provided an opportunity for practice effects, leading to better performance on the priming task. It is still unclear, though, why eight year old children had the biggest increase in baseline identification levels between the pilot study and the experiment. In sum, the pilot study was not as useful as hoped. Greater overlap between the pilot and experimental
methodology likely would have provided more accurate pilot data. Therefore, other alternatives for determining baseline identification abilities across age are recommended.

This experiment has provided reasonably strong confirmatory evidence that implicit memory remains stable from age 4 into early adulthood. Further, it attained the goal of replicating the relative developmental trends of implicit and explicit memory without methodological shortcomings. Thus, it serves as a solid foundation from which one may ask other theoretically interesting questions. For instance, researchers may use the picture fragment completion task with older adults to chart implicit memory across the entire life span.

Another interesting research possibility is to look at the characteristics of implicit memory in learning disabled and mentally retarded individuals. Replication of Lorsbach & Worman's (1989) findings of equivalent priming in learning disabled and normal children is necessary. Likewise, there is recent evidence that children with Down Syndrome show normal savings on relearning (Newman, 1991). Both of these populations would be excellent candidates for testing with the picture fragment completion paradigm. If priming is normal in these populations, it may be possible to facilitate learning in these disadvantaged individuals by tapping into implicit memory processes (e.g. Glisky & Schacter, 1987).
Another area for future research concerns findings of modality specificity. It is unclear whether or not priming shows the same modality specificity in children as it does in adults (e.g. Roediger & Weldon, 1987). Also, because children with Down Syndrome have specific deficits in auditory explicit memory (Bilovsky & Share, 1965; Rohr & Burr, 1978), future research may investigate the possibility that auditory implicit memory could be impaired relative to visual implicit memory in this population. Such a finding could also have important implications for rehabilitation.

It now appears quite probable that priming remains developmentally stable from age four to adulthood. Likewise, explicit memory, as measured by cued recognition, improves throughout childhood. These results are strengthened by utilization of the retrieval intentionality criterion, which experimentally dissociated the two memory systems at all ages. Clearly, after replication of these results, many exciting theoretical and applied challenges remain.
APPENDIX A: PILOT STUDY INSTRUCTIONS

Children:

Initial Instructions: I have a picture naming game to play with you. I am going to show you some pictures of objects. They could be anything, like a clown, or a rocketship or a house. I want you to tell me what they are. Now, if I were to show you a whole picture of a clown, I think you could name the picture pretty easily. So guess what I did! I took away some of the picture, so at first, you'll only see a little bit of the picture and you guess what it is. It's Okay if you don't know what it is. I'll show you a little more of it. I'll keep on showing you more and more of the picture until you guess what it is. It is important that you gave fun, but you must also try as hard as you can. The answers you give me during the game are very important. Hopefully, they will help children who aren't as lucky as you learn in school. You can stop playing any time you want, so tell me if you want to stop and go back to Mrs. ____________'s class. I won't feel bad if you want to stop. So remember, your job is to figure out what each picture is as soon as you can. Are you ready to play?

After child names the first picture: That was good! You see, [experimenter lays out entire set in front of child], each picture is of the same object, except I took out more and more of it to make it easier as you go along. Let's do another one. [Experimenter takes away first set].
On second, third and fourth sessions: Do you remember when we looked at objects and you tried to name them? The objects could be anything, like a rocketship or a clown. Well, today I have some different objects for you to name. Just like last time, I'll only show you a little bit of the object at first, and then I'll show you some more and some more until you guess what the object is. It's Okay if you don't know what the object is or you guess incorrectly. Just try to figure out what the object is as soon as you can. Remember, you may stop playing at any time. Just tell me if you want to stop. It won't make me feel bad. Also, it's important that you have fun playing, but you must try as hard as you can. Hopefully, the answers you give me when we play will help me learn about children who have difficulty learning. Are you ready?

Adults:

I am interested in finding out at what point people can identify common objects. First, I have a brief questionnaire for you to fill out. Then I will show you some sets of pictures of objects and measure the point at which you can identify them. You have the right to stop participating at any time. You will still receive credit for the study, even if you stop early. The information you give me today will be totally anonymous. What questions do you have?

[Experimenter answers all questions.] Let's begin. [Subject completes demographic questionnaire.] Now I am going to show you some sets of
pictures of objects, like an orange or a clown. The first picture of each set will be very incomplete. After that, every picture in the set will be a bit more complete. For example, I might first show you a picture of 15% of a house, then 25% of a house, then 40%, then 60%, 80%, 90% and so on. After I show you each picture, I want you to tell me what you think the object is. Your goal is to correctly identify the object as soon as you can. It's alright if you don't know at first or if you guess incorrectly. Just tell me that you think the object is. Two sets will never contain pictures of the same object. For instance, I won't show you two sets of pictures of clowns. If you want, we can take periodic breaks, since there are so many pictures. Remember, you can stop participating at any time you wish. Questions?

[Experimenter answers any questions the subject has.] Let's begin.
APPENDIX B: EXPERIMENT LISTS

<table>
<thead>
<tr>
<th>List A</th>
<th>List B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf*</td>
<td>Leaf*</td>
</tr>
<tr>
<td>Stove/Oven*</td>
<td>Stove/Oven*</td>
</tr>
<tr>
<td>Cow*</td>
<td>Cow*</td>
</tr>
<tr>
<td>Cup/Teacup*</td>
<td>Cup/Teacup*</td>
</tr>
<tr>
<td>Bird</td>
<td>Snake</td>
</tr>
<tr>
<td>Wheel</td>
<td>Shoe</td>
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<tr>
<td>Bed</td>
<td>Table</td>
</tr>
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<td>Apple</td>
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<tr>
<td>Pig</td>
<td>Elephant</td>
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<tr>
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<td>Door</td>
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<tr>
<td>Airplane</td>
<td>Helicopter</td>
</tr>
<tr>
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<td>Rabbit</td>
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<td>Spoon</td>
<td>Bottle</td>
</tr>
<tr>
<td>Chair</td>
<td>Church</td>
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<td>Bee</td>
<td>Butterfly</td>
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<td>Car</td>
<td>Bicycle</td>
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<tr>
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<td>Dog</td>
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<tr>
<td>Clock</td>
<td>Television</td>
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<tr>
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<td>Corn</td>
</tr>
<tr>
<td>Fish</td>
<td>Horse</td>
</tr>
<tr>
<td>Mitten</td>
<td>Glove</td>
</tr>
</tbody>
</table>

* Distractor words to (a) decrease primacy effects and (b) increase subject’s familiarity with the encoding task.
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