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EXAMINATION OF THE HABIT AND COGNITIVE MEMORY SYSTEMS IN CHILDREN

by

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Abstract

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by

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Habit and cognitive memory have been proposed by Mishkin and Petri (1984) as distinct systems for retaining experience in humans and primates. These memory systems have been found to be dissociated in terms of their developmental trajectories in monkeys and very young children, and have been found to be differentially affected by brain lesions in monkeys and adult humans. In this dissertation, performance of school-age children on tasks designed to separately assess habit and cognitive memory was examined. A third task, in which some trials placed previously formed habit memory in competition with accurate cognitive memory performance, was also administered. The sample consisted of 81 normal children, divided into three age-groups (age ranges were 5.5 to 7.49 years, 7.5 to 9.9 years, and 10 to 14.5 years). Results indicated a significant effect of age on the test of cognitive memory, but not on the habit memory task. These findings are related to data from the human and animal literature, which indicate that habit memory reaches its mature form earlier in development than does cognitive memory. The presence of previously encountered habit task stimuli as recognition alternatives appeared to improve cognitive memory performance for all age-groups. However, the youngest group demonstrated less facilitation than the two older groups in the context of previously reinforced recognition alternatives. Alternative explanations for this finding are discussed.

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INTRODUCTION

Mishkin and Petri (1984) proposed the existence of two forms of retention abilities, which they termed habit and cognitive memory. The habit system is thought to support the acquisition of skills and habits based on a gradual build-up of stimulus-reward associations (i.e., habit strength) via repeated presentations. In contrast, the cognitive memory system is identified with conscious, effortful memory processing, such as that used for retaining information over a delay (e.g., recognition or recall tasks) (Mishkin & Appenzeller, 1987).

The habit and cognitive memory systems provide an explanatory model for the pattern of deficits and preserved abilities seen in experimentally lesioned animals and in humans with memory disorders (Malamut, Saunders & Mishkin, 1984). While amnesic patients and non-human primates with limbic lesions have been found to be impaired on tests of cognitive memory, relative sparing on tests of non-cognitive memory has been noted in these same subject groups (i.e., habit formation, procedural memory) (Malamut, Saunders & Mishkin, 1984; Schacter & Moscovitch, 1984). In addition, habit and cognitive memory have been differentiated in both animal and human studies on the basis of developmental trajectories (Bachevalier & Mishkin, 1984; Overman, Bachevalier, Turner & Peuster, 1990). However, little attention has been paid to the way in which these systems interact to determine behavior. The habit and cognitive memory systems are dissociable under particular circumstances, yet Mishkin views them as typically acting in concert (Mishkin & Appenzeller, 1987).

One goal of this dissertation was to examine the development of habit and cognitive memory in normal children, aged 5.5 to 14.5 years. Tasks were developed to separately assess the two forms of memory. These tasks were closely modeled after paradigms used to study cognitive and habit memory skills in monkeys. A second aim of this dissertation was to examine the way in which the habit and cognitive memory systems might interact in determining subjects' responses. To do this, a third task was used to assess the degree to which previously formed habit memory would affect performance on a cognitive memory task. This task was a cognitive memory task, and contained some trials in which responding according to prior habit memory was inconsistent with correct cognitive memory performance.

Swanson and Cooney (1991) note that memory is a skill which is inseparable from intellectual functioning and learning, and that the efficiency of memory processes is likely to be manifested in a number of academic and cognitive domains. In keeping with this view, the relationship of performance on the habit and cognitive memory measures to intellectual functioning, reading ability, attentional functioning and behavior ratings was examined.

Background

Although historical antecedents of schemes for distinguishing between different forms of memory have been described, memory was generally conceptualized as a unitary system throughout the first half of the twentieth century (Polster, Nadel & Schacter, 1991). Since then, research has revealed that memory is a multi-faceted process, and researchers have struggled to understand the complexity of memory phenomena. Various dichotomies and subdivisions of memory have been proposed, but it is likely that no one scheme is able to fully encompass the richness of all memory-related phenomena.

Although this study focussed on the habit/cognitive memory dichotomy, in the interest of clarity, a discussion of other proposed divisions is provided. Some of these include: semantic versus episodic memory, explicit versus implicit memory and procedural versus declarative memory. Semantic memory is considered to be knowledge of general facts which are not restricted to a particular context, whereas episodic memory refers to knowledge of specific events (Squire, 1982). Explicit memory is seen as deliberate recollection, as revealed through recall and recognition tasks, while implicit memory involves facilitation of performance on tasks due to prior exposure to stimuli, and is not dependent on deliberate recall of the prior experience (Schacter & Moscovitch, 1984). Procedural memory consists of perceptual or motor skill learning, whereas declarative memory denotes consciously retrievable memory for stimuli and experience (Saint-Cyr, Taylor & Lang, 1988).

The relationships among these various memory subdivisions are complicated by the fact that they are neither conceptually independent nor fully overlapping with each other. It would seem that part of the lack of integration of different memory schemes is due to the fact that some of the categories are theory-derived, others are task-determined, and still others come from clinical observations of patients with naturally-occurring brain damage.

Attempts have been made to integrate the different memory subdivisions. DiGiulio, Seidenberg, O'Leary and Raz (1994) proposed that semantic and episodic memory can be viewed as subdivisions of declarative memory. Explicit and declarative memory also appear interchangeable, while implicit and procedural memory have been grouped, along with classical conditioning, under the rubric of non-conscious or non-declarative memory (Schacter, 1987; Deweer, et al., 1994). Factors common to procedural and implicit memory include the fact that knowledge acquired through them is often not available for verbal report, that such memory abilities appear early in development, and that they are relatively resistant to the effects of brain damage (McKee & Squire, 1993; Musen & Squire, 1992; Schacter & Moscovitch, 1984). Findings in implicit memory studies are often directly compared to findings in procedural memory studies (Deweer, et al., 1994).

Whether implicit and procedural memory should be seen as representing the same underlying process is unclear. While the terms "implicit" and "procedural" are often used interchangeably in the literature, it appears that researchers studying implicit memory phenomena at times fail to consult the literature on procedural memory, and *vice versa* (Green & Shanks, 1993). Procedural and implicit memory differ significantly in terms of the nature of the tasks used to assess them. Procedural memory is usually studied via multi-trial presentation of stimuli or tasks, whereas a single presentation is often used in studies of implicit memory. In addition, there are data to suggest that procedural and implicit memory can be dissociated (Heindel, Salmon, Shults, Walicke & Butters, 1989; Schwartz & Hashtroudi, 1991). Further investigation of these processes is necessary before complete equivalence between implicit and procedural memory should be assumed.

Mishkin's Model of Habit and Cognitive Memory

Despite the variety of memory schemes offered, there is general convergence between the animal and human memory literatures regarding the distinction between a memory system that subserves recognition and recall of specific items or episodes on the one hand, and a habit or skill learning system that is involved in incremental response acquisition on the other (Polster, Nadel & Schacter, 1991; Tulving, 1985). An example of such convergence is Mishkin's habit/cognitive memory dichotomy (Mishkin & Petri, 1984), which is based primarily on research with animals. This dichotomy is virtually identical to the distinction between procedural and declarative memory, which is based on research with amnesic patients. Noting the similarity between the preservation of memory formation via repeated presentations combined with profound disturbance of memory on other tasks in animals and the procedural/declarative dissociation seen in human amnesic patients, Mishkin and Petri (1984) proposed a model consisting of two memory systems.

The habit system is hypothesized to mediate the retention of stimulus-response associations such as those between objects and reward contingencies (Mishkin & Petri, 1984). This type of memory is thought to involve little conscious effort, and knowledge gained through this system may not be readily accessible to conscious awareness. Like procedural memory, habit memory is acquired gradually, through repeated exposure to stimuli, and is not affected by manipulations that severely compromise cognitive memory (Malamut, Saunders & Mishkin, 1984).

In contrast, the cognitive system is hypothesized to support rapid, one trial memory formation, and encoding of information regarding specific situations and episodes, as demonstrated in stimulus recognition and recall of declarative information (Overman, Bachevalier, Turner & Peuster, 1992). According to Mishkin and Petri (1984), the products of the declarative (or cognitive) system are "memories" while the products of the procedural system have been termed "habits". Because of the high degree of similarity of findings relating to the habit/cognitive and procedural/declarative memory systems, these terms are used interchangeably in subsequent sections of this dissertation.

Not only can these memory systems be differentially defined, but developmental and lesion data support their dissociation. Studies with monkeys have indicated that the habit system reaches functional maturity earlier in primate development than does the cognitive system (Bachevalier & Mishkin, 1984). Similarly, preliminary research with small numbers of human subjects supports the proposal that the habit and cognitive memory systems display divergent development, with the cognitive system becoming functionally mature later than the habit system (Overman, et al., 1992). Anatomically, the habit system appears unaffected by medial temporal lesions in monkeys, which cause significant interference in the functioning of the cognitive memory system (Malamut, Saunders & Mishkin, 1984). Consistent with this, the human memory disorders literature is replete with findings of preserved non-cognitive (i.e. procedural) memory in the context of significant impairment in cognitive memory processes (For review, see Moscovitch, 1982; see also Tranel & Damasio, 1993).

Mishkin does not intend an artificial separation between these memory systems, and suggests that they usually act in concert. That is, a particular experience usually involves both memory systems, although there exist circumstances where one or the other may be dominant. Further, it is unlikely that development proceeds in an all or nothing, habit to cognitive transition, but rather that there is a change in the relative dominance of the two systems in determining the responses of the organism during different developmental stages.

Evidence for the Dissociation of Habit/Procedural and Cognitive/Declarative Memory

Gaffan (1974) found that fornix-lesioned monkeys displayed poor performance on a test of recognition memory in which they were required to indicate which of two items in a pair had been presented prior to a delay (delayed match-to-sample). In contrast, these same monkeys performed equivalently to controls on a task in which they were reinforced for choosing a previously rewarded object and for rejecting previously non-rewarded objects. Gaffan concluded that fornix lesions had resulted in a loss of recognition memory, while leaving "association memory" intact in the monkeys. Furthering this line of research, Malamut, Saunders and Mishkin (1984) found a marked difference in the performance level of monkeys with medial temporal lobe lesions on two different types of memory tasks. In one task, a delayed match to sample test, pairs of stimuli were presented which included one novel stimulus and one that had been presented prior to a delay. The monkeys were required to choose the previously presented object in order to receive reinforcement. The other task, the object discrimination test, required the monkeys to learn, through multiple presentations separated by 24-hour inter-trial intervals, which of a pair of objects was consistently reinforced. Reward valence in this task was randomly assigned, i.e., not based on prior presentation of any of the stimuli. Malamut, Saunders and Mishkin (1984) found that monkeys subjected to bilateral amygdalo-hippocampal lesions were impaired on the delayed response task but were able to learn the object discrimination task at a level comparable to intact animals.

A similar dissociation of memory processes has been noted in the pattern of impaired and preserved abilities of human amnesic patients. Typically, patients who are amnesic (e.g. as a result of hippocampal resections or Korsakoff's Disease) display deficits on many standardized memory tasks as well as in day-to-day functional memory (e.g., not remembering their doctors). These patients may recall very little, if anything, of their experiences even minutes after they occurred and may have particular difficulty with memory over a delay (Schacter & Moscovitch, 1984). However, it is now apparent that even patients with severe amnesia have intact retention for aspects of experiences which occurred after the onset of their amnesia. This retained experience is evident in its modification of ongoing behavior. Specifically, even in severe cases of amnesia, normal or near normal levels of classical conditioning, implicit memory and procedural memory have been observed (Squire, 1982). Evidence of such preservation of certain memory abilities in amnesics is found in clinical anecdotes as well as in controlled studies.

Evidence for preservation of procedural memory was described in studies of the patient H.M., who became severely amnesic after bilateral temporal resection for the treatment of intractable epilepsy. H.M. demonstrated increasing proficiency on a variety of motor skills, despite the fact that he could not recall ever having encountered the tasks before (Milner, Corkin & Teuber, 1968). Other skills which have been found to be preserved in amnesic patients include: proficiency at jigsaw puzzle assembly (Brooks & Baddely, 1976), acquisition and application of a mathematical rule (Wood, Ebert & Kinsbourne, 1982), solution of the Tower of Hanoi problem (Cohen, 1984), and mirror reading (Cohen & Squire, 1980; Moscovitch, 1982).

Amnesic patients have been found to display impaired performance on memory tasks initially developed for research with animals. Prisko (1966; cited in Schacter & Moscovitch, 1984) found that H.M's performance on a delayed match-to-sample task was quite impaired (i.e., equivalent to that of a normal six- month-old human infant). Although H.M. could perform the task when no delay between presentation and choice existed, his performance deteriorated to chance levels at delays of 25 seconds.

Squire, Zola-Morgan and Chen (1988) examined the performance of patients with various forms of amnesia on the delayed response and object discrimination tasks. They found the expected impairment in amnesic patients on the delayed response test. However, they did not find a dissociation with regard to object discrimination performance. The human amnesics were unable to learn a 20-pair object discrimination task presented at 24-hour inter-trial intervals, a task which "amnesic" monkeys are able to master (Malamut, Saunders & Mishkin, 1984; Overman, Bachevalier, Turner & Peuster, 1992).

Subject and methodological variables may account for the discrepant findings of the study by Squire et al. (1988). The authors suggest that humans and monkeys may approach the object discrimination task differently, and that human subjects may use declarative memory processes when learning which of two objects is consistently reinforced. The stimuli used in their study, similar to those used by Malamut, Saunders and Mishkin (1984), were "easily discriminable junk objects," such as toys, food containers, etc. This type of stimulus easily lends itself to being verbally labeled. Indeed, Squire et al. stress the role of language processes, noting that the performance of their patients on the various memory tasks correlated with their ability to verbally describe the task principles and stimulus materials. Thus, differences between the patterns of results obtained with human and monkey subjects may be due to the confounding effect of language. In addition, the sample used in this study was small and somewhat heterogeneous, consisting of eight patients (five with Korsakoff's syndrome and three with amnesia resulting from anoxia or ischemia), thus limiting the statistical power and generalizability of the results. Finally, given that the findings of this study indicated poor performance on both types of memory tasks, one wonders about the presence of interfering factors, such as reduced attention/motivation. Such factors might have caused a generalized low level of performance across both types of tasks and masked potential differences in memory abilities. Thus, replication of this finding with a larger sample would be helpful in investigating possible species differences in terms of the dissociability of memory systems. Nevertheless, this study highlights the difficulties inherent in assuming that a task developed in research with animals assesses the same cognitive function in human subjects.

A recent case study presented by Tranel and Damasio (1993) illustrates another example of dissociation among memory abilities. Data were presented on a patient, whom they call Boswell, who suffered bilateral damage to the entire medial temporal lobe (including the amygdala, entorhinal cortex and hippocampus) and interconnected cortices in the anterior temporal and medial frontal regions. This patient had a severe memory deficit for all types and levels of knowledge, including faces. Indeed, Boswell was unable to recognize faces of persons with whom he had had extensive contact since the onset of his amnesia. Despite his profound memory impairment, he was able to demonstrate acquisition of associations (described as "non-conscious bonds") between pictures of people and the affective valence they were associated with. Three staff members, whom the patient had not met, were assigned to a particular style of interacting towards Boswell. One (the "good guy") was always kind to Boswell and always granted him treats (candy, drinks, etc.). The "bad guy" refused Boswell's requests for such treats and was responsible for having Boswell perform tasks that he did not like (e.g., participating in boring experiments). The "neutral guy" behaved in a business-like manner and did not grant requests nor was he responsible for experiments which Boswell did not like. After five days of exposure to the consistent interaction styles of these staff members, Boswell was shown their pictures in a multiple choice format and asked to choose the one he would "go to for a treat". He demonstrated a reliable preference for the face of the "good guy" over that of the "neutral" and "bad guys" when each was presented along with an unfamiliar face, but was unable to overtly recognize these faces. Tranel and Damasio used Mishkin's habit/cognitive dichotomy to explain Boswell's intact ability to form affective associations in the context of a profound memory impairment, and suggest that Boswell was able to form these associations via his intact neostriatum and parietal, occipital and posterior temporal cortices.

What is most striking about the dissociations described above is that amnesic patients not only usually perform better on "non-cognitive" tasks than on standard, effortful recall/recognition memory tasks, but that they perform at or near normal levels on these tasks. This pattern, in which normal subjects are no better than amnesic individuals on a given task can be taken as evidence that declarative memory is not required for performance. That is, if declarative memory is useful for performing a particular task, than amnesic patients should necessarily perform at a level below that of persons with intact memory abilities (Schacter, 1985). The above findings suggest that performance on non-cognitive tasks is mediated by a memory system which is separate from that which is damaged in amnesia and assumed to be responsible for the severely impaired performance seen on many traditional memory measures. The system which appears intact in amnesia is described by Schacter and Moscovitch (1984) as one that is "not consciously accessible", and "whose operation is inferred from observed facilitations in performance on tasks that do not require the organism to relate its performance on the task deliberately to any past experience" (p.178). The memory system that is damaged in human amnesia is the one that "entails conscious access to recently established representations of events and information," (p. 178) and has frequently been studied in the adult literature via free and cued recall, and yes/no or forced choice recognition.

Evidence of memory that is not accessible to conscious awareness has been also found in studies of normal human adults. Lewicki, Czyzewska, and Hoffman (1987) and Lewicki, Hill and Bizot (1988) demonstrated that normal adults were capable of learning a complex pattern of stimulus positions in a computerized visual search task, as evidenced by increased accuracy and decreased reaction times with continued practice on the task. However, no subject was able to articulate knowledge of the pattern. Similarly, Montare (1992) found that an equivalent level of procedural memory in a sample of 62 college students was accompanied by differing levels of "declarative cognizance" relating to the task rules. That is, despite the fact that all subjects were able to master a discrimination learning task, the sample was divisible into subgroups, according to the level at which they were able to verbalize the discrimination rule. Lewicki, Czyzewska, and Hoffman (1987) suggested that the phenomenon of "unconscious knowledge acquisition" typifies a general property of information processing, whereby some aspects of experience automatically prime appropriate responses when relevant stimuli are encountered, without entering into conscious awareness. In addition, Lewicki, Hill and Bizot (1988) suggest that non-conscious acquisition of knowledge increases the functional processing capacity of the human cognitive system. Sherry and Schacter (1987) suggest that the non-conscious or procedural memory system may accomplish this by gradually acquiring information via extracting invariances across learning episodes.

Dissociations between declarative and non-declarative forms of memory in normal adult human subjects have also been delineated via experimental manipulations. For instance, recognition memory, but not perceptual identification reaction time or accuracy (i.e., priming), is improved by requiring more elaborate stimulus processing (Jacoby & Witherspoon, 1982), and recognition memory declines over one week, whereas priming does not (Musen & Treisman, 1990; Tulving, Schacter & Stark, 1982). In addition, priming has been found to be independent of recognition memory at the level of individual task stimuli, i.e., subjects may demonstrate priming for visual patterns they do not recognize and *vice versa* (Musen & Treisman, 1990). Thus, these studies indicate that cognitive and non-cognitive forms of memory differ along various dimensions and can be distinguished even in normal adults.

Developmental Studies

Further delineation of the cognitive and habit memory systems has been provided by an examining their development in monkeys. Bachevalier and Mishkin (1984) examined the performance of monkeys at three, six and twelve months of age on delayed non-matching to sample and object discrimination tasks. They showed that three-month old monkeys displayed poor performance on the delayed non-matching to sample task as compared to adult (three-year-old) monkeys. Ability to perform the delayed response task increased significantly with age, but the monkeys had not reached adult proficiency at one year of age. In addition, even after the infant monkeys had mastered the delayed non-matching to sample task, their performance was more adversely affected, as compared to adult monkeys, by memory "challenges" in the form of list presentations and longer delays. In contrast to their relative difficulty on the delayed response test, infant monkeys were able to form visual object discrimination habits as quickly as adult animals. Thus, this experiment extended the differentiation of the two memory systems into the developmental realm, and suggests that the habit memory system matures significantly earlier than the cognitive memory system in monkeys.

Research concerning human memory development has demonstrated reliable improvement in recall and recognition abilities during childhood and adolescence (DiGiulio, Seidenberg, O'Leary & Raz, 1994; Hoffman & Dick, 1976; Siegler, 1991). Most of this research, however, has been conducted with verbal stimuli (e.g. words, stories) or material that is easily verbalizable (e.g., pictures of objects). Although studies of memory for verbal material have important implications for academic learning, use of verbal stimuli may confound memory performance with verbal abilities.

There is some debate regarding the relative importance of metacognitive or strategic and basic processes in memory development. Boyd (1988) notes that a dominant theme in the current literature is that developmental memory changes reflect, in large part, the increasing proficiency in the use of strategies with age. Kail and

Hagen (1982) describe a universal sequence of development of cognitive strategies. It is rare to witness spontaneous strategy use in children below the age of six, while between seven and ten years of age, use of strategies begins to emerge. This is seen as a transitional period, during which implementation of strategies becomes more consistent and refinement occurs in the strategies themselves. After this, a period of consistent strategy use is described, representing a mature state.

Thus, much of the recent literature on memory development in children is concerned with the acquisition of second-order processes which impact on the proficiency of memory performance. However, it has been argued that with regard to the development of memory span, individual and developmental differences account for only a modest amount of subject variance, whereas non-strategic variables, such as identification speed and speech rate are highly correlated with span performance (Hulme, 1986). In turn, speed of identification and rate of speech are highly correlated with general speed of information processing, which itself shows a developmental increase (Kail, 1991).

Examination of the development of basic memory processes in children have been conducted. Schacter and Moscovitch (1984), based on a review of the infant memory literature, proposed an early- and a late-developing memory system to account for younger and older infants' qualitatively different memory performance. These differences include the findings that novelty preferences of younger infants (six to nine months), but not of 12-month-old infants, were eliminated by cross-modal changes between presentation and test, and that younger infants were unable to perform delayed matching to sample tests at delays longer than 250 milliseconds, whereas twelve-month-olds performed above chance levels at delays up to 12 seconds. Schacter and Moscovitch proposed that the early-developing system supports novelty-habituation preference formation and some forms of conditioning and is similar to the system that is spared in amnesics (i.e., procedural memory). The late-developing memory system is proposed to be necessary for tasks such as object search and recognition, and is not available until the latter part of the first year of life. The defining characteristics of this system appear quite similar to those of declarative memory. A lag in development of the declarative memory system has been proposed to account for the phenomenon of infantile amnesia, or the lack of conscious recollection in adult life for events in the early years of life (Bachevalier, 1992).

Overman, Bachevalier, Turner and Peuster (1992) studied habit and cognitive memory development in young children, and compared their results to those found with non-human primates. They examined the ability of human children, ranging in age from 12 to 32 months, as well as adults, to learn delayed response and object discrimination tasks using “junk objects” as stimuli. Results indicated that, although rate of learning the object discrimination task did improve with age, human infants were able to efficiently learn object discriminations by 12 months, but required "prolonged training and maturation" in order to learn the delayed response task. In contrast, adults learned both tasks easily. In addition, as compared to adults' performance, young children's performance on the delayed response test was more negatively affected by memory "challenges", such as increasing the number of items to be remembered (i.e., a list format) or increasing the length of delay. Thus, Overman et al.'s results indicate that learning which object in a repeatedly presented pair will be reinforced is a much easier task for human infants than remembering which of two objects was presented prior to a delay.

Overman et al. (1992) note that this differential level of performance at different ages cannot be accounted for by differences in attention, perception, motivation, or stimulus- reward associations since these factors were equivalent across the two tasks. In addition, the reduced ability of human infants to learn the delayed response test was not accounted for by perseverative response tendencies. Overman et al. suggested that the object discrimination and delayed response tests require different cognitive processes that are mediated by two neural systems which mature at different times. The fact that rate of learning the object discrimination test improved with age may be accounted for by the fact that adults were able to form declarative memories of the easily verbalizable junk objects to supplement habit memory, whereas this alternative was not available to the infants. This suggestion is similar to the proposal by Squire, Zola-Morgan and Chen (1988) with regard to their data.

While Overman et al. (1992) studied performance of human infants on tasks developed to assess habit and cognitive memory abilities, few detailed examinations of these processes beyond infancy/early childhood have been undertaken. Overman et al. did examine the performance of a small group of children (n = 7) between the ages of 40 and 81 months on the delayed response test, but not the object discrimination task. They noted that, although these older children were able to perform the task with a significant degree of accuracy (mean = 78% correct), their scores were significantly poorer than those of adults. Thus, it appears likely that there is continued development of delayed response ability between infancy and later childhood, although the small sample and broad age grouping in the Overman et al. (1992) study did not permit detailed investigation of possible continued developmental change. In addition, no study has been found which examined object discrimination performance or the interaction between the two systems in older children.

Although examination of the continued development of habit and cognitive memory has not been carried out, research with children on the conceptually related implicit/explicit memory dichotomy has produced some interesting results. Lorsbach and Worman (1989) investigated the development of implicit and explicit memory processes in normal and learning disabled third and sixth grade children. They found that the older children were able to recall/recognize more pictorial information than the younger children on tests involving explicit memory (cued and free recall). In addition, learning-disabled children performed at a significantly lower level than normals on the same test. Such differences were not apparent on measures of implicit memory (picture fragment completion), i.e., younger and older children, as well as learning-disabled and non-learning-disabled displayed equivalent performance on this task. These results suggest that implicit memory ability for pictures does not change significantly with development, at least between the third and sixth grades. Further, this ability appears intact in learning disabled children, a group which had difficulty on tests assessing more effortful, explicit forms of memory (i.e., cued and free recall).

DiGiulio, Seidenberg, O'Leary and Raz (1994) examined the development of two forms of memory (which they termed declarative and procedural) in groups of eight and twelve-year-old children. No significant effect of age was noted in the amount of priming facilitation apparent in the identification of degraded versions of previously presented words and pictures. In contrast, the 12-year-old children were able to verbally recall significantly more items than were the eight-year-olds. DiGiulio et al. concluded that there was a developmental dissociation of the two memory processes. Although they labeled these processes procedural and declarative memory, they are probably better characterized as implicit/explicit memory, particularly given the striking similarity between their methodology and that used by Lorsbach and Worman (1989). In addition, their use of only verbal recall of items raises the question of whether the age differences found might be due to language or retrieval processes rather than memory for the presented items per se. Nevertheless, the pattern of findings suggesting that the more automatic, or less cognitive, process showed little developmental difference between younger and older individuals is similar to that found in developmental studies of the habit and cognitive memory systems in monkeys. The consistency across species suggests that a developmental dissociation between an automatic, habit-based memory system and a more cognitive form of memory may be a universal characteristic of mammalian memory.

Anatomical Underpinnings

Cognitive/declarative memory function has been proposed to be dependent on a cortico-limbo-diencephalic circuit, based on research examining the effects of experimental lesions in animals and the results of focal brain damage in humans. According to Bachevalier (1992), highly processed sensory information from the cortex is projected to the amygdala and indirectly to the hippocampus through the perirhinal and entorhinal cortices. Information from the amygdala and the hippocampus is then projected to the medial thalamus and the mammillary bodies. Bachevalier notes that these diencephalic regions are connected to medial temporal cortex as well as medial prefrontal cortex, which then project to the basal forebrain, which itself has widespread connections with most cortical areas. Compromise of this anatomical circuit is presumed to be responsible for the impaired conscious recognition ability seen in human amnesia (Squire, Zola-Morgan & Chen, 1988) and experimental disruption of this system causes marked deficits on the delayed response task in lesioned monkeys (Bachevalier & Mishkin, 1984).

Because of the consistent finding of preserved habit/procedural memory in animal and human amnesia, the biological substrate of this system has been proposed to be independent of the cortico-limbic-diencephalic circuit. A corticostriatal circuit has been suggested as its anatomical basis (Mishkin & Appenzeller, 1987). Mishkin and Appenzeller note that the striatum, by nature of its connections from many areas of cortex, including those which process sensory information, as well as with those that control movement, is well suited to "provide the relatively direct links between stimulus and action" that are characteristic of habits (p. 89).

Other memory researchers have also suggested a role for the striatum and its connections in the preserved abilities of amnesic patients on tasks of procedural memory (Butters, Wolfe, Martone, Granholm & Cermak, 1985; Tranel & Damasio, 1993). Saint-Cyr, Taylor and Lang (1988) provided support for this proposal in a study revealing a selective deficit for procedural memory in patients with Parkinson's Disease, a disorder characterized by basal ganglia dysfunction. They found evidence in such patients of impaired procedural memory coupled with preserved declarative memory. Specifically, these patients displayed normal performance on tests of verbal recall (i.e., declarative memory), but were impaired on a modification of the Tower of Hanoi task, a task frequently used to assess procedural memory. This task requires the subjects to learn the series of "moves" that would result in a particular configuration of colored blocks, with the restrictions that only one block can be moved at a time and a darker color cannot be placed on a lighter color. Patients with advanced Parkinson's Disease have also been found to be impaired on a rotor pursuit task, another test of procedural memory which requires subjects to learn to keep a stylus in contact with a rotating target (Heindel, Salmon, Shults, Walicke & Butters, 1989).

Dissertation Overview and Rationale

The goal of this study was to examine the development of and interrelationship between habit and cognitive memory processes. Normal children between 5.5 and 14.5

years of age performed tasks designed to differentially assess habit and cognitive memory. In addition, the children's performance was examined on a task in which some trials placed previously formed habit memory in competition with cognitive memory performance.

Computer tasks were developed to assess the habit and cognitive systems. The Object Discrimination Task (ODT) consisted of fixed pairs of non-verbalizable figures which were presented repeatedly. One figure in each pair was "correct," and was consistently reinforced throughout the task. Since accurate performance on this task required repeated experience with the figures, and involved the gradual development of a reward association with one of the shapes in a pair and not the other, this task was thought to rely primarily on habit memory. The ODT used in this study was directly modeled after that used by Malamut, Saunders and Mishkin (1984), in which 10 pairs of "junk objects" were presented at 24-hour inter-trial intervals. One object in each pair was consistently reinforced, while the other was consistently not reinforced when chosen by the monkeys.

The ODT used in this study differs from Bachevalier and Mishkin's task in terms of the computerized task presentation, the nature of the stimuli and in the length of the inter-trial interval. Computerized presentation was chosen in the interest of standardization and practical ease of administration. Shapes which were not easily verbally labeled were chosen in order to decrease the impact of language abilities on test performance. An inter-trial interval shorter then 24 hours was chosen for practical considerations.

The Simple Delayed Response Test (Simple DRT) was a delayed match-to-sample task, in which subjects were presented with a list of visual figures, and then asked to identify which of a pair of figures they had seen in the list. Because this task required the subject to remember specific information over a delay in order to respond correctly, and was based on a one trial presentation, performance of this task was thought to rely on the cognitive memory system.

A third task, the Complex Delayed Response Test (Complex DRT) was similar to the Simple DRT described above, except that some of the incorrect recognition alternatives were figures that had been previously presented (and either reinforced or not reinforced) as part of the Object Discrimination Task. Previously presented figures were used as recognition alternatives in order to assess the impact of previously formed habit memory on cognitive memory performance, both in conditions where responses according to cognitive and habit were consistent with each other and where they were in conflict. Specifically, in trials in which the incorrect recognition alternative was a figure that had been previously reinforced in the ODT, responding according to habit memory would result in errors. A higher rate of errors in this Complex DRT trial condition could be interpreted as a greater relative influence of habit memory, as opposed to cognitive memory, in determining responses. In contrast, in trials in which the incorrect recognition alternative was an ODT figure that had never been reinforced, habit and cognitive memory were consonant with one another, and responding according to previously formed habit memory would not interfere with cognitive memory.

Since the previously reinforced and previously non-reinforced incorrect recognition alternatives used in the Complex DRT were presented an equal number of times in the ODT, these stimuli were matched in terms of amount of exposure and any differences seen in response accuracy on these two trial types could be interpreted as due to the reinforcement contingencies associated with them. In the trials in which a neutral (i.e., novel) figure was used as the incorrect recognition alternative, previously formed habit memory had no bearing on current accurate cognitive memory performance. These trials served as a reference point for the influence of previously reinforced and previously not reinforced incorrect recognition alternatives on the accuracy of cognitive memory performance.

Thus, although the Complex DRT assessed delayed visual recognition of visual figures, as did the Simple DRT, it contained the added complexity that some of the incorrect recognition alternatives were figures to which the subjects had already learned responses. It was hypothesized that this manipulation would place an additional requirement on the children in that they had to inhibit responding to previously reinforced ODT stimuli in some trials.

Significant age-related improvements were expected in cognitive memory skill, as assessed by Simple DRT performance. However, it was expected that all three age-groups would demonstrate an equivalent level of habit memory formation, as assessed by ODT performance. This, in combination with the research literature which suggests poorer inhibitory abilities in younger children (Dempster, 1992), led to the prediction that younger children would be less likely to inhibit previously formed habits and thus would make more errors on the Complex DRT, specifically in those trials containing a previously reinforced recognition alternative. In other words, it was thought that the cognitive memory of younger children would be more vulnerable to being "overridden" by previously formed habit memory.

The DRTs used in this study were directly modeled after paradigms used to study cognitive memory in animals (Bachevalier & Mishkin, 1984; Overman et al., 1992). A list-type presentation, (also used by Overman et al., 1992), was chosen because pilot testing indicated that single item presentation and response trials were too easy, (i.e., even very young children made few errors). The DRTs used in this study differ from those used in previous studies in terms of their computerized format and use of abstract shapes as opposed to "junk objects," as discussed above for the ODT. In addition, a match-to-sample rule was adopted in this study, as opposed to the non-match-to-sample used by Bachevalier and Mishkin (1984). This change was made in order to accommodate the manipulation used in the Complex DRT, i.e., in order to put the two types of memory abilities in competition with one another, responses had to be made according to which stimulus had just been presented as opposed to which one was novel. Additionally, verbal instructions were used (see Appendix B), which is not possible when assessing recognition memory in non-human subjects.

In addition to the memory tasks described above, measures of IQ, reading ability, attentional functioning and behavior in school and at home were also used. These measures were included in order to determine whether habit and cognitive memory proficiency was related to these other important domains of functioning. The

WRAT-R Reading Subtest was also used to screen for the presence of learning disabilities.

This study had three main analyses, which examined 1) developmental changes on the ODT and Simple DRT; 2) the effect of preexposed recognition alternatives on DRT performance (i.e., Complex DRT); and 3) Complex DRT error patterns across age-groups. All three analyses were characterized by a mixed experimental design, with Age-group and Gender as the between-subjects factors, along with a within-subjects factor. In the first analysis, the within subjects factor was Task (ODT vs. Simple DRT). In the second analysis, the within-subjects factor was also Task (Simple DRT vs. Complex DRT). In the third analysis, Complex DRT Trial Condition (i.e., reinforced, non-reinforced or novel) was the within-subjects factor.

Hypotheses

The main predictions regarding the results of this study were the following:

1) A significant effect of age would be found on the cognitive memory task (Simple DRT).

2) A significant effect of age would not be found on the measure of habit memory (ODT).

3) Younger children would experience greater difficulty on the Complex DRT (specifically in those trials in which the incorrect recognition alternative was previously reinforced in the ODT), in comparison to both their own Simple

DRT performance as well as to the Complex DRT performance of older children.

In addition to the main hypotheses outlined above, a number of secondary predictions were also made. Since the memory stimuli were designed to be relatively independent of verbal labeling, it was predicted that performance on these tasks would not demonstrate significant relationships with performance on measures of verbal abilities (e.g., reading, Verbal IQ). Findings from research on human memory development have not emphasized gender differences in retention abilities. Thus, significant gender effects were not expected in this study. No specific predictions regarding the relationship between memory task performance and behavior ratings were made.

METHOD

Subjects

The initial sample consisted of 85 children (46 boys and 39 girls) between the ages of 5.5 and 14.5 years, recruited from suburban elementary schools. Exclusion criteria were the presence of mental retardation, specific developmental disorder, neurological abnormality or psychiatric disorder, and a primary language other than English. Three boys were excluded from further analysis based on parental information regarding the presence of psychiatric diagnoses. One child was diagnosed with a learning disability and two children were diagnosed with Attention-deficit

Hyperactivity Disorder, according to parents' reports of doctors'/psychologists' diagnoses. In addition, a fourth boy was uncooperative with testing.

A learning disability, independent of parent report, was judged to be present if a child met the following conditions: 1) a 15-point discrepancy (one standard deviation) between performance on tests of reading ability and assessed intelligence (administered as part of this research protocol); and 2) reading ability one standard deviation below the mean for the child's age. No child in the sample qualified as learning disabled according to these criteria. Thus, a final sample of 81 children was used for data analysis (42 boys and 39 girls).

The sample was divided into three groups: those 5.5 to 7.49 years ($n = 27$; mean age = 6.6 years), those 7.5 to 9.9 years inclusive ($n = 26$; mean age = 8.6 years) and those 10.0 to 14.5 ($n = 28$; mean age = 12.1 years). These divisions were chosen in order to form three relatively equally-sized groups. Descriptive characteristics for these age groups are presented in Table 1. Statistical analyses of the three age-groups revealed no significant between-group differences regarding gender composition [Chi-square = .111, ns], IQ (as assessed by KBIT Composite IQ) [$F (2,78) = .822$, ns] or reading ability (as assessed by WRAT-R performance) [$F (2,78) = 1.044$, ns].

Table 1

Age-group Characteristics

Variable	5.5 -7.49 years	7.5 - 9.9 years	10 - 14.5 years
N	27	26	28
Mean Age (SD)	6.57 (.67)	8.56 (.73)	12.06 (1.21)
M/F Ratio	14/13	14/12	14/14
KBIT (SD)	107.78 (8.91)	110.69 (8.04)	107.89 (10.81)
WRAT Reading (SD)	106.22 (14.37)	106.88 (8.72)	110.21 (8.92)

Experimental Tasks

The memory tasks consisted of the Object Discrimination Test (ODT), designed to assess habit memory, the Simple Delayed Response Test (Simple DRT), developed to assess cognitive memory, and the Complex Delayed Response Test (Complex DRT), developed to assess the interaction between habit and cognitive memory.

All memory task stimuli were presented on a Toshiba 3300SL laptop computer and consisted of non-representational shapes based on a 1.5 inch square array. For each figure, pieces of the square were "cut out," resulting in a wide variety of images, all having approximately the same surface area. Examples of task stimuli are presented in Appendix A. A large pool of such shapes was initially assembled, and shapes were randomly assigned to each memory task. Through pilot testing, shapes which easily evoked verbal labels from children were eliminated from the tasks and another shape from the pool was substituted.

For all three memory tasks, subjects responded to the task stimuli by pointing to the shape of their choice, at which point the experimenter recorded their response by pressing a computer key located below the shape. This method of response was chosen because pilot testing indicated that when young children pressed the key themselves, they tended to look only at the keyboard and not give sufficient attention to the task stimuli. Four practice trials were completed by the subjects on each of the tasks to ensure that they understood the procedures, as indicated by three correct responses in a row. No child required more than this amount of practice. A token reinforcement system was used, wherein a plastic bead was placed into a jar each time the child made a correct response. At the end of each session, the children "traded in" their tokens for a toy, which they chose from several alternatives (e.g., stickers, plastic figures, pencils, etc). Those subjects who earned up to 250 tokens (of a possible 590) were allowed to choose one toy, while those who earned more than 250 tokens were allowed to choose two toys. Verbatim instructions for the memory tasks are detailed in Appendix B.

Object Discrimination Task (ODT) The ODT consisted of the presentation of pairs of figures. The subjects were told that it was a guessing game, and that they should try to guess which of the two figures was correct, and point to the correct figure. The figures remained on the screen until a response was made.

When the correct figure was chosen, the computer emitted a song-like series of beeps, and verbal reinforcement was given by the examiner (e.g., "That's right" or "Very good"), and a token reinforcement was given. When the incorrect figure was chosen, the computer made no sound and the examiner said "No, not that one" or "That one didn't beep."

The ODT included 25 blocks of stimuli. Blocks consisted of ten discrete figure pairs, which were counterbalanced with regard to left/right screen position, resulting in a total of 20 pairs per block. Within each block, ten reinforced stimuli appeared in the left position and ten appeared in the right position. The same counterbalanced pairs were repeated throughout all blocks of the task, cycling through four randomized orders. Fifteen blocks were completed during the first test session (see below), presented in sets of three blocks, with task filled intervals (i.e., completion of other tasks in the battery - see below) between each set. An additional ten blocks were presented during the second test session, in sets of three and two blocks, which were also separated by task filled intervals.

Dependent measures from the ODT were the total number of correct responses across all blocks, and the number of blocks completed before reaching a criterion of 90% correct (i.e., 18/20 responses correct in one block).

Delayed Response Tests (DRTs) Two types of DRTs (Simple and Complex) were used. Each DRT consisted of five blocks of six trials, resulting in a total of 30 trials. Each block consisted of the consecutive presentation of a list of six stimulus figures, followed by six recognition trials. The presentation duration for each stimulus was three seconds. The interstimulus interval was two seconds, after which time the subject was cued for the next stimulus presentation by the examiner, e.g., "Look at this one". The delay between each presentation figure and its corresponding recognition pair was forty seconds. The subjects were asked to point to the figure in each pair that they "just saw before, by itself". Correct responses were reinforced via computer "beeps," as well as by verbal and token reinforcement. When an incorrect response was made, the computer made no sound, no token reinforcement was given, and the experimenter said "No, not that one". Each DRT required approximately five minutes to administer.

The Simple and Complex DRTs differed only in terms of the particular shapes used and the nature of the figures presented as recognition alternatives. The presentation figures used in both versions of the DRT were novel to the subjects, having been drawn from a larger pool of shapes and then randomly assigned to each task.

Simple DRTs The Simple DRT used only novel stimuli as incorrect recognition alternatives (foils). There were two forms of this task. One form of the Simple DRT was presented on Day 1 (Simple DRT #1) and one on Day 2 (Simple DRT #2), in order to determine whether practice effects were operative.

Complex DRT The Complex DRT had the same format as described for the Simple DRT. Incorrect recognition alternatives in this task consisted of three types of stimuli: 1) novel (not previously seen by the subjects), 2) previously reinforced in the ODT, and 3) previously seen in the ODT but not reinforced. Ten trials presented the correct stimulus in combination with a novel stimulus, 10 trials presented the correct stimulus in combination with a previously reinforced stimulus, and the remaining 10 trials presented the correct stimulus in combination with a pre-exposed but not reinforced stimulus. All ODT figures were used as incorrect recognition alternatives in the Complex DRT. Errors occurring in each of the three trial types are referred to as novel, reinforced and non-reinforced, respectively.

The three trial conditions (i.e., novel, previously reinforced and previously not reinforced incorrect stimuli) occurred in randomized blocks of three, with each type of trial condition occurring once in every three trials. The trial conditions were also balanced according to their order in the list, in order to control for serial position effects (i.e., primacy and recency). Reinforcement contingencies were identical to those described for the Simple DRT. Measures from the Complex DRT included the number correct as well as the number of errors in each of the three trial conditions.

Non-Experimental Measures

In addition to the above-described experimental measures, indices of general intellectual functioning, single word reading ability, performance on a brief vigilance task, and behavior in school and at home were assessed. The measures used included the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990), the Conners Parent Questionnaire (Goyette, Conners & Ulrich, 1978), the IOWA Conners Teacher Questionnaire (Loney & Milich, 1982), the Reading Subtest from the Wide Range Achievement Test - Revised, (Jastak & Wilkinson, 1984), and a brief continuous performance test, adapted from Halperin, et al., (1988). A brief description of each task is provided below. Parents were asked to complete a brief questionnaire which assesses the presence of exclusionary characteristics, such as visual or auditory deficits, learning disability, psychiatric or neurological diagnosis, and dominance of another language in the home.

Kaufman Brief Intelligence Test (KBIT) The KBIT was used to provide an estimate of general intelligence. This test consists of two separate scales for assessing verbal and non-verbal abilities (Vocabulary and Matrices, respectively) and was used to characterize the sample with regard to IQ.

Behavior Rating Scales The IOWA Conners Teacher Questionnaire (CTQ) was used to gather information about the children's behavior in school. This scale generates two factors: Inattention/Overactivity and Aggression. The Conners Parents Questionnaire (CPQ) was used to assess the children's behavior at home. This scale also generates several factors, among which those assessing Conduct Problems and Impulsivity-Hyperactivity were selected, given their correspondence to the domains assessed by the IOWA CTQ.

Wide Range Achievement Test - Revised, Reading Subtest The Reading Subtest of the Wide Range Achievement Test - Revised (WRAT-R), which requires reading single words aloud, was used to assess decoding ability, and to screen for the presence of a learning disability.

Continuous Performance Test A brief continuous performance test (CPT), which was a shortened version of the CPT developed by Halperin et. al. (1988), was administered in order to assess attentional functioning and impulsivity level. This test required the subject to watch a series of letters presented on the computer screen, and to press the space bar whenever they saw an "A" followed by an "X". Practice trials were presented prior to task performance in order to insure that the subject understood the task. The task lasted six minutes, and scores on measures of inattention, impulsivity and dyscontrol were computed (see Halperin et. al., 1988, for description of error analysis).

Procedure

Participation in this study consisted of the completion of two test sessions, separated by one week. After informed consent was obtained from a parent or guardian, children were asked for their verbal agreement to participate in the study. Testing was conducted in a quiet room in the child's school, or in a quiet area of the child's home. Each session lasted approximately 45 minutes. The tasks, as well as their order of presentation, are listed in Table 2.

The order of the last two tests (Simple DRT #2 and Complex DRT) was counterbalanced across subjects to control potential order effects. Half of the sample received the Simple DRT #2 first, immediately after the last block of the ODT. The other half of the sample received the Complex DRT first. For this group, a five minute rest period (equivalent to the administration time of the Simple DRT) took place between the ODT and the Complex DRT, in order to keep the delay between the ODT and the Complex DRT constant across all subjects. The overall order of test administration was chosen with the aim of distributing ODT block administration across the test sessions as well as making the length of the two sessions as equal as possible.

Data Analysis

To test the hypothesis that a significant effect of age would be found on Simple DRT performance, but not on ODT performance, a mixed, three-way analysis of variance (Task by Age-group by Gender) was conducted. The dependent measures for

Table 2

Task Order

First Session	Second Session
ODT (3 Blocks)	ODT (3 Blocks)
3 minute rest period	CPT
ODT (3 Blocks)	ODT (2 Blocks)
WRAT-R Reading Subtest	KBIT - Expressive Vocabulary
ODT (3 Blocks)	ODT (3 blocks)
KBIT- Matrices Subtest	KBIT - Definitions Subtest
ODT (3 Blocks)	ODT (2 Blocks)
Simple DRT # 1	Simple DRT # 2*
ODT (3 Blocks)	Complex DRT*

*The order of these tasks was counterbalanced (see text) this analysis of variance (ANOVA) were z-score transformations of 1) the mean of total number correct responses on Simple DRT #1 and Simple DRT #2 (Mean Simple DRT); and 2) the total number of correct responses on the ODT across all blocks. Because data for Simple DRT #2 were missing for nine subjects, mean Simple DRT was replaced by Simple DRT #1 for these subjects. A significant Age-group by Task interaction, such that mean Simple DRT performance, but not ODT, showed a significant effect of age would provide support for the hypothesis.

Further post-hoc analysis of the age effects on the Simple DRTs (#1 and #2) as well as the number of trials to criterion on the ODT was conducted via separate ANOVAs. More specific characterization of age-group differences on the memory measures was carried out via ANOVAs and post hoc comparisons using Tukey's Honestly Significant Difference statistic.

The prediction that younger children would make more errors on the Complex DRT, both in relation to their own Simple DRT performance and in relationship to the Complex DRT performance of older children, was tested via a mixed three-way ANOVA (Age-group by Task by Gender). Dependent variables for this analysis were the mean of the number of correct responses on Simple DRT #1 and #2 (mean Simple DRT) and the number correct in the Complex DRT. Gender was included in this analysis to rule out significant effects of this variable. A significant Age-group by Task interaction, and no significant main effects or interactions of gender could be interpreted as supporting hypothesis #3 as stated.

To briefly review, there are three trial conditions in the Complex DRT, each characterized by the nature of the incorrect recognition alternative presented with the correct figure. Incorrect recognition choices are either Novel (i.e., not encountered in any prior memory task), Non-reinforced (i.e., presented in the ODT but never reinforced), or Reinforced (figures used in the ODT and consistently reinforced). To test the prediction that younger children, would demonstrate a different error pattern than older children, a mixed three-way ANOVA (Trial Condition by Age-group by Gender) was conducted for the Complex DRT. A significant Trial Condition by Age-group interaction would provide support for this hypothesis. Post hoc analyses examining error rates across age groups were conducted via one-way ANOVAs, while analysis of the three error types within age-groups was conducted via multiple t-tests using Bonferroni's correction to control for the inflated alpha levels.

Additional questions regarding the relationships among measures assessing habit and cognitive memory, as well as between these measures and non-experimental measures were examined via correlational and factor analysis. Bonferroni's correction was used when multiple tests were employed.

Because the order of the Simple DRT #2 and the Complex DRT was counterbalanced, order effects were a potential finding. This was investigated via mixed two-way ANOVA (Age-group by Order) on the total number of correct responses in the Simple DRT #2 and the Complex DRT. To more closely examine the effect of test order on Complex DRT error distribution, a mixed two-way ANOVA was carried out, using Order as the between subjects factor and Trial Condition as the within subjects factor. Further characterization of significant findings from the above analyses was carried out via more specific one-way ANOVAs and t-tests.

RESULTS

The principal findings from this study are those that are directly related to the main hypotheses concerning: 1) the potential dissociation of developmental patterns for the habit and cognitive memory tasks and 2) the proposed difference in Complex DRT total performance and error patterns across age-groups. The relevant data and their analyses, which are presented in the initial subsections of the Results section, provide a fairly clear answer to the questions raised. The effect of gender was also examined in these principal analyses. Although significant effects of gender were not predicted, the sample consisted of relatively equal numbers of males and females and potential gender differences were seen as relevant to the generalizability of these findings. Following subsections present results concerning relationships between measures and potential order effects.

Age and Gender Effects on Simple DRTs and ODT

Mean scores of the different age-groups on measures from the Simple DRT and the ODT are presented in Table 3. Visual inspection of the data indicates that there was little change across Age-groups in the total number of correct responses on the ODT. In contrast, mean Simple DRT performance improved with age. The mixed three-way ANOVA examining Age-group, Gender and Task effects on z-score transformations of mean Simple DRT score and ODT score revealed a significant age-group by task interaction [$F(2,75) = 5.97$, $p < .005$], as well as a significant main effect of Age-group [$F(2,75) = 6.12$, $p < .005$]. No significant main effects or interactions of Gender were found. Figure 1 depicts the performance on these measures for the three age groups, presented as z-scores.

To further characterize the Age-group by Task interaction found above, the effects of age on DRT and ODT performance were examined separately. An ANOVA performed on the mean Simple DRT performance revealed a significant effect of Age-group [$F(2,78) = 13.86$, $p < .001$]. Post hoc analyses of mean Simple DRT performance, conducted via Tukey's HSD revealed that all three age groups were significantly different from one another, with the youngest group scoring the lowest, the oldest group scoring the highest and the middle age-group falling in between.

Similar findings resulted when performance on the two Simple DRTs was examined separately. A oneway ANOVA examining the effect of Age-group on Simple DRT #1 performance revealed a significant effect of age [$F(2,78) = 11.81$, $p < .001$]. Post hoc analysis via Tukey's HSD indicated that both the middle and oldest groups performed better than the youngest group, but did not differ from one another. When the effect of Age-group on Simple DRT #2 was examined, a main effect of age was again found [$F = 2, 69) = 11.16$, $p < .001$], with the oldest group performing significantly better than the middle and youngest groups, which did not differ significantly from one another.

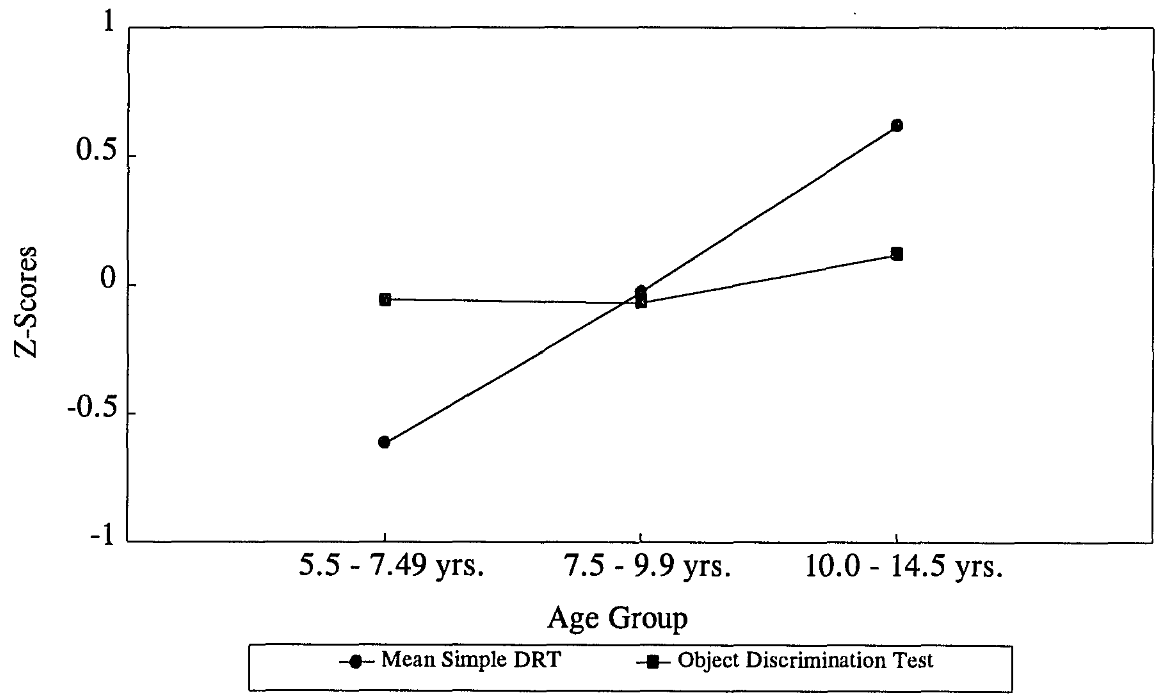
Table 3

Age differences on memory measures (mean number correct)

Measure	5.5 - 7.49 yrs.		7.5 - 9.9 yrs.		10 - 14.5 yrs.	
	Age-Group					
	Mean	(sd)	Mean	(sd)	Mean	(sd)
ODT total correct	353.1	(54.6)	352.4	(55.4)	362.2	(48.8)
ODT Trials to criterion	16.5	(6.6)	17.4	(6.9)	16.9	(7.3)
Mean Simple DRT	18.9	(2.7)	20.9	(3.0)	23.1	(3.0)
Simple DRT #1	18.8	(3.2)	21.3	(2.8)	22.8	(3.2)
Simple DRT #2	18.8	(3.0)	20.1	(4.1)	23.5	(3.8)

Figure 1

Standardized scores on Mean Simple DRT and ODT



In contrast to the significant and consistent age effect found on the DRTs, a one-way ANOVA of variance examining total correct responses on the ODT revealed no significant effect of age (F (2,78) = .297, ns). Similarly, there was no significant effect of age on the number of blocks needed to reach the 90% learning criterion for the ODT [F (2,78) = .103, ns]. Learning curves on the ODT for the three age groups are presented in Figure 2, and indicate a very close correspondence in level of learning across ODT blocks in the three age-groups.

Complex DRT

The mean number correct of the three Age-groups on the Simple DRT and the Complex DRT are presented in Table 4. A mixed three-way ANOVA (Age-group by Gender by Task) was conducted on the mean number of correct responses in the two Simple DRTs and the total correct in the Complex DRT, with Age-group and Gender as the between-subjects factors and Task (i.e., Simple or Complex DRT) as the within-subjects factor. Although significant main effects were found for both Age-group [F (2,75) = 20.45, $p < .001$] and Task [F (1,75) = 33.61, $p < .001$], the Age-group by Task interaction was not significant. There was no significant main effect of Gender [F (1,75) = 1.59, ns], nor were there any significant interactions involving Gender.

The significant effect of Task was in the direction opposite to that which had been predicted. Performance on the Complex DRT was more accurate than that on the Simple DRT for all three age- groups. In order to determine whether this effect could be accounted for by practice effects, a mixed three-way ANOVA was conducted on the

Figure 2

Learning Curves on ODT

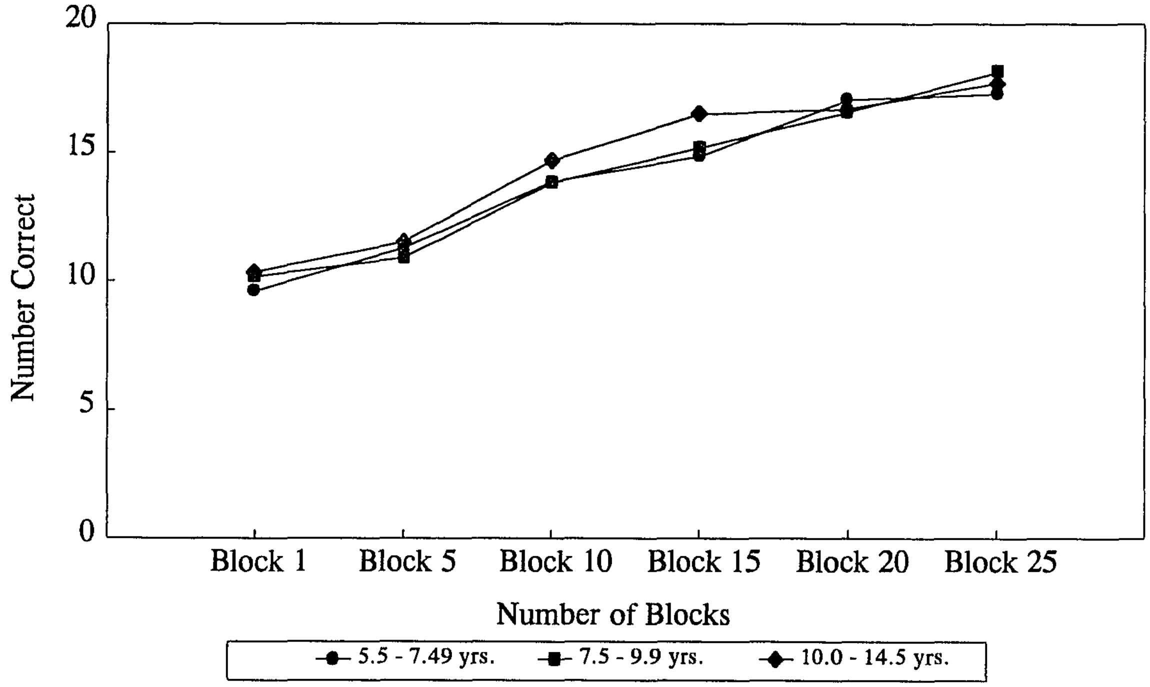


Table 4

Mean number correct in Simple and Complex DRT's

	Age-Group					
	5.5 - 7.49 yrs		7.5 - 9.9 yrs.		10 - 14.5 yrs.	
Task	Mean	(sd)	Mean	(sd)	Mean	(sd)
Mean Simple DRT	18.9	(2.7)	20.9	(3.0)	23.1	(3.0)
Complex DRT	20.0	(4.1)	23.3	(3.8)	25.5	(2.0)

total correct in Simple DRT #1 and Simple DRT #2 (Task by Age by Gender). This analysis revealed no significant main effects or interactions of Task, indicating lack of significant practice effects operating over the two days of testing on the Simple DRTs.

Table 5 presents the mean number of correct responses in the three trial conditions of the Complex DRT for each age-group. A mixed three-way ANOVA of Complex DRT data (Trial Condition by Age-group by Gender) resulted in significant main effects of Trial Condition ($F(2,150) = 68.59$, $p < .001$) and Age-group [$F(2,75) = 17.25$, $p < .001$], as well as significant Age-group x Trial Condition [$F(4,150) = 4.10$, $p < .05$] and Gender x Trial Condition [$F(2,150) = 3.99$, $p < .05$] interactions. The main effect of Trial Condition was due to the fact that each age-group made more errors in the novel condition than in the reinforced or non-reinforced condition. The main effect of Age-group resulted from the fact the youngest group made significantly more errors across all three trial conditions than did the older group.

In order to examine age-group differences in more detail, separate ANOVAs were conducted for the number of correct responses in each of the three trial conditions. These analyses revealed significant effects of age on novel errors [$F(2,78) = 3.29$, $p = .04$], non-reinforced errors [$F(2,78) = 6.93$, $p = .002$], and reinforced errors [$F(2,78) = 31.02$, $p < .001$]. Post hoc analyses of novel errors via Tukey's HSD indicated that no two Age-groups differed significantly from one another. For non-reinforced errors, the oldest group performed significantly better than the youngest group, with the middle age-group falling in between. With regard to reinforced errors,

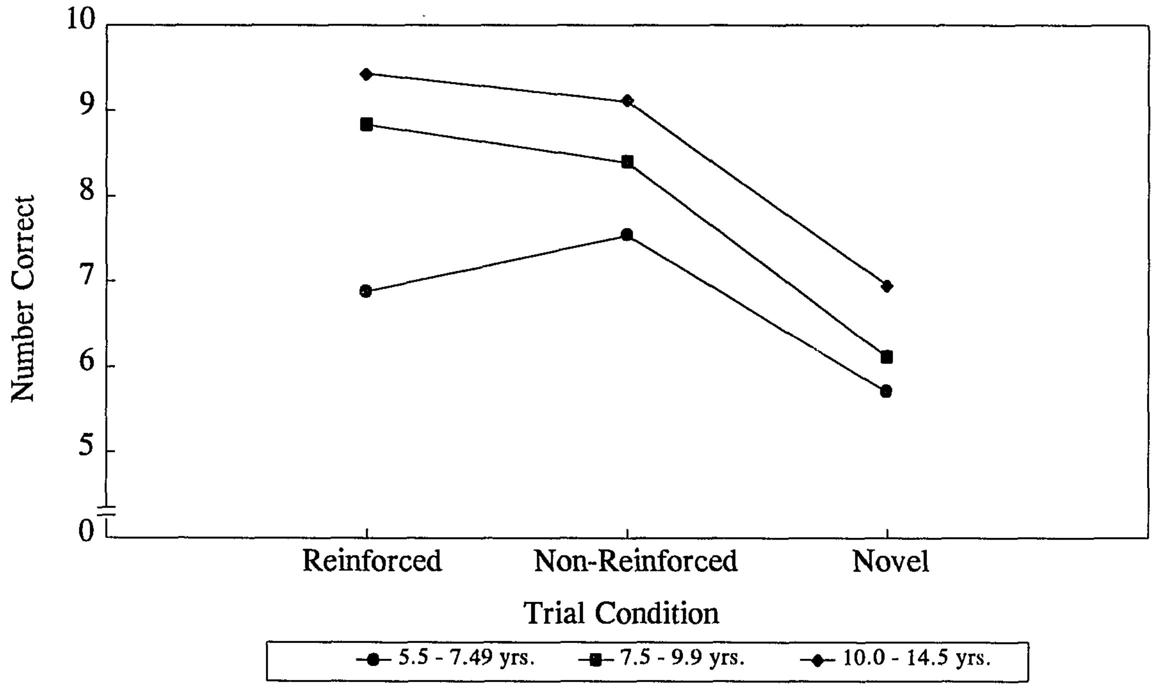
Table 5

Mean number correct in Complex DRT trial conditions

	Age-Group					
	5.5 - 7.49 yrs.		7.5 - 9.9 yrs.		10 - 14.5 yrs.	
Trial Condition	Mean	(sd)	Mean	(sd)	Mean	(sd)
Novel	5.8	(2.0)	6.0	(1.7)	7.0	(1.6)
Non-Reinforced	7.4	(1.9)	8.4	(1.9)	9.1	(1.0)
Reinforced	6.8	(1.8)	8.9	(1.2)	9.4	(.7)

Figure 3

Number Correct in Complex DRT Trial Conditions



both the middle and oldest age-groups performed significantly better than the youngest group, while not differing from each other.

The significant Age-group by Trial Condition interaction can be seen in Figure 3. Whereas the older and middle groups performed significantly better ($p < .001$) in the reinforced as compared to the novel condition (i.e., made fewer reinforced than novel errors), in the youngest group this difference did not reach the significance level needed using Bonferonni's correction for inflated alpha levels (.05/9 t-tests = .006) ($t = 2.12$, $p = .042$). In addition, whereas the older and middle groups performed best in the reinforced condition, the youngest group performed best in the non-reinforced condition. The number of non-reinforced errors was significantly lower than the number of novel errors for all three age-groups, while no group demonstrated a significant difference between the number of reinforced and non-reinforced errors.

The significant Gender x Trial Condition interaction was accounted for by the fact that boys made significantly fewer errors in the novel trial condition than did girls. No other trial condition revealed a significant gender effect.

Relationships Among Measures

Examination of the interrelationships among the memory measures, using partial correlations controlled for age, revealed significant relationships among the delayed response tests (see Table 6). The Simple DRTs displayed no significant relationship with ODT performance. The total number of correct responses on the ODT was significantly correlated with performance on the Complex, but not Simple, DRT.

Table 6

Relationships among memory measures [1]

	Simple DRT #2	Complex DRT	ODT Total correct
Simple DRT #1	r = .385*	r = .400*	r = .157
Simple DRT #2		r = .428*	r = .162
Complex DRT			r = .373*

[1] - values represent partial correlations controlled for age
* - significant at or below p = .005

In order to further examine the relationship between ODT performance and the improvement noted in scores between the Simple and Complex DRT, the difference between the mean Simple DRT score and the Complex DRT was computed for each subject. This difference score was then correlated with total correct responses on the ODT. This analysis revealed a small, but significant, correlation ($r = .241$, $p < .05$).

The correlations between the memory measures and indices of intelligence and reading ability are presented in Table 7. None of the memory measures were related to reading ability. Although the Simple DRT #1 was significantly related to composite KBIT score (IQ), and showed trends toward significance in its relationship with KBIT Vocabulary and KBIT Matrices scores, these correlations fell far short of the significance level needed in the context of multiple correlations (.05/16 = .003). Partial correlations controlling for age yielded no significant relationships between CPT variables and memory measures.

To more clearly examine associations among the memory measures, intelligence and reading ability, a Principle Components factor analysis using Varimax rotation was carried out. The variables entered into the analysis were age, and scores on the following variables: Simple DRT #1, Simple DRT #2, Complex DRT, ODT total correct, raw KBIT Vocabulary score and raw KBIT Matrices score. Results are presented in Table 8. Two factors emerged, which, combined, accounted for a total of 74.3% of the variance. Factor 1 accounted for 59.9% of the variance, and contained significant loadings from age, all DRT tasks and both KBIT scores. Factor 2 accounted

Table 7

Correlations between memory measures and intelligence and academic measures

	Simple DRT #1	Simple DRT #2	Complex DRT	ODT Total Correct
WRAT Reading	.123	.008	.027	-.006
KBIT Vocabulary	.210**	.181	.169	.157
KBIT Matrices	.213**	.083	.126	.185
KBIT Composite	.246*	.157	.176	.204

* - $p < .05$
** - p = or $< .06$ (trend)

Table 8

Factor Analysis of Selected Variables

	Rotated Factor Matrix	
	Factor 1	Factor 2
Age	.917	.002
Simple DRT #1	.698	.281
Simple DRT #2	.670	.324
Complex DRT	.667	.516
ODT Total Correct	.051	.930
KBIT Vocabulary	.880	.076
KBIT Matrices	.933	.095

for 14.4% of the variance, and contained a very high loading for ODT score and a moderate loading for the Complex DRT.

Relationships among the memory measures (i.e., Simple and Complex DRT, ODT, and performance on the three trial conditions in the Complex DRT), with the Inattention/Overactivity and Aggression factors from the IOWA CTQ and the Impulsivity/Hyperactivity and Conduct Problems factors from the CPQ were examined via partial correlation coefficients, controlled for age. Only the correlation between total number of correct responses on the ODT and the score on the CPQ Conduct Problems factor ($r = -.350$; $p = .002$) was significant at the level necessary after Bonferroni's correction for multiple correlations (i.e. .05/ 28 = .002).

Order Effects on Task Performance

The order of Simple DRT #2 and the Complex DRT were counterbalanced so that potential order effects on task performance could be examined. Gender was not included in these analyses, as previous results had indicated a lack of significant gender effects on Simple DRT and Complex DRT performance. A two-way ANOVA (Age-group by Order) on total correct in Simple DRT #2 revealed no significant main effects or interactions of task order. With regard to performance on the Complex DRT, a two-way ANOVA (Age-group by Order) revealed a significant effect of Age-Group [$F (2,66) = 24.38$, $p < .001$) and Order [$F (1,66) = 7.69$, $p < .05$) on total correct responses but no significant Age-group by Order interaction. The significant main effect of Order indicated that, for the sample as a whole, performance was more accurate on the Complex DRT when it was given before the Simple DRT #2, as compared to the reverse order (i.e., Simple DRT #2 preceding Complex DRT).

The effect of task order on performance across the three trial conditions in the Complex DRT was examined via a mixed three-way ANOVA, with Age-group and Order as between subject factors and Trial Condition as the within subjects factor. This analysis revealed a significant main effect for Order [$F(1,66) = 7.21$, $p < .05$](and Trial Condition as seen in the previous analysis), but no Age-group by Order interaction. Separate one-way ANOVAs examining the effect of Order were performed on each of the Complex DRT trial conditions. No significant effect of order was found for novel errors. A significant effect of order was found for non-reinforced errors, such that the subjects made fewer errors when the Complex DRT preceded Simple DRT #2 as opposed to vice versa [$F(1,70) = 6.33$, $p < .05$]. Reinforced errors also displayed this pattern, although the effect of Order did not reach significance [$F = (1,70) = 3.24$, $p = .076$]. Because of the presence of these order effects, the analyses involving Complex DRT performance and the Age-group by Trial Condition interaction were redone, using task order as a covariate. The results of these analyses remained essentially unchanged.

DISCUSSION

The primary aim of this dissertation was to determine whether there are different developmental trajectories for habit and cognitive memory in children, and whether the nature of their relative dominance in determining responses would vary as a function of age. It was predicted that while cognitive memory performance would improve significantly as a function of age, habit memory would not display a marked age effect. In addition, it was predicted that the cognitive memory of younger children, as compared to older children, would be more easily disrupted by prior habit memory that was inconsistent with current accurate cognitive memory performance.

The hypothesis of an age-related dissociation between habit and cognitive memory performance received strong support from the results of this study. All of the delayed response tasks showed significant effects of age, with older children performing more accurately than younger children. In contrast, no age effect was found for the ODT, either for the number of total correct responses, or for the number of trials needed to reach a 90% correct learning criterion.

These results suggest that visual recognition of a previously presented stimulus, an ability assumed to be subserved by the cognitive memory system, continues to improve throughout childhood. However, the ability to form associations between visual stimuli and reinforcement contingencies (i.e., visual habit formation) does not show such developmental change, at least across the age range used in this study (5.5 to 14.5 years of age). Although it is possible that habit memory proficiency develops further during adolescence and early adulthood, this seems unlikely. This developmental dissociation between the two forms of memory appears characteristic of both boys and girls, who showed equivalent performances on virtually all experimental measures at each age level. The one exception to this is the finding that boys were significantly more accurate in the novel trial condition of the Complex DRT. As this is the only significant gender-related difference found among multiple analyses, it is difficult to know whether it is meaningful or is merely a chance finding. Overall, these results are consistent with Bachevalier and Mishkin's (1984) theory that habit memory is developmentally more primitive, appearing earlier in its mature form, while cognitive memory performance is a more gradually developing ability throughout childhood.

Additional evidence for a distinction between habit and cognitive memory was found by examining the relationships among experimental measures. Correlational analyses, controlled for age, revealed a lack of significant relationships between the Simple DRTs and the ODT, suggesting independence between performance on measures of habit and cognitive memory. In addition, factor analysis of these data revealed two factors, one primarily characterized by high loadings of age, DRT performance and IQ measures (Factor 1), and the other characterized by a very high loadings for the ODT and a moderate loading for the Complex DRT (Factor 2). This suggests that cognitive, but not habit, memory is closely associated with cognitive development and performance on traditional measures of intellectual functioning.

This study extends research on the development of habit and cognitive memory in children into older ages than have previously been studied. Overman et al. (1992) focussed on significantly younger children. Their findings indicated that while human infants (aged 12-32 months) were able to learn discrimination tasks easily, they required prolonged training and maturation in order to master a delayed non-matching to sample task. In addition, Overman et al. (1992) found that the performance of children, as compared to adults, was more severely affected by increasing the cognitive memory load (i.e., list length or delay), providing further evidence of the greater immaturity or vulnerability of the cognitive memory system in very young children. Although Overman et al. (1992) did include a small group of older children (40 - 81 months), and found that their performance on the delayed response task was also significantly poorer than adults, the habit and cognitive memory proficiency of these older children was not a primary focus of their study. The results of the current investigation suggest that the development of the cognitive memory system continues throughout childhood, beyond the ages investigated by Overman et al. (1992), while confirming that no further development of habit memory occurs during this age span.

The results of this dissertation are quite similar to those of DiGiulio et al. (1994), who found an age-related dissociation on tests of implicit and explicit memory in groups of eight- and twelve-year-old children. Their findings indicated an age-related increase in verbal recall scores for previously presented stimuli (a declarative/explicit memory task), but no age difference in recognition facilitation of these same stimuli (a paradigm traditionally used to study implicit memory). Despite the potential conceptual difficulties presented by using implicit and procedural memory interchangeably, their results do lend support to the proposal that a conscious, effortful form of memory has a more prolonged developmental trajectory than does a more automatic form. They concluded that procedural memory is functionally mature by at least middle childhood, while declarative memory continues to advance over the same age range. The current study goes beyond that of DiGiulio et al. in terms of the wider age range studied, as well as the comparability of response condition across tasks in which a developmental dissociation was found.

Taken together, these studies provide support for the validity of the distinction made between a conscious, effortful form of memory, and one that is more automatic (i.e., declarative/cognitive vs. procedural/habit). These memory subtypes have been clearly delineated and distinguished in terms of the pattern of deficits and preserved abilities seen after brain damage (i.e., in humans and animals) (Malamut, Saunders & Mishkin, 1984; Squire, 1982). In addition, a growing body of literature indicates early attainment of mature proficiency on tasks designed to assess non-declarative memory, coupled with more prolonged developmental change in declarative memory performance (Bachevalier & Mishkin, 1984; Overman, et al., 1992). The developmental primacy of the habit or procedural memory system can be interpreted within the context of the need for a platform upon which later declarative knowledge can accrue. The habit system can be seen as providing the means through which behavior-reinforcement contingencies are instilled in the developing organism. The establishment and influence of such contingencies are the *sine que non* of behavior change based on experience, an important component of development.

There is evidence that the habit and cognitive memory systems have distinct neural substrates (Malamut, Saunders & Mishkin, 1984). While experimental and clinical data attest to the importance of limbic sites for the intact function of cognitive/declarative memory (Overman et al, 1992; Squire, Zola-Morgan & Chen, 1988; Philips, Malamut, Bachevalier & Mishkin, 1988), several authors have nominated subcortical brain regions, particularly the striatum, as forming the biological foundation of habit memory (Bachevalier & Mishkin, 1988; Saint-Cyr, Taylor & Lang, 1988).

In addition to identifying the neural regions which subserve these memory processes at a mature developmental stage, determination of the underlying structural and functional brain changes underlying developmental improvement (i.e., in declarative memory) is also of interest. Because of the continued development of proficiency in declarative/cognitive memory ability during childhood and into adolescence, attention has turned to those brain areas which continue to demonstrate developmental change during this developmental period. Brain maturation throughout childhood involves myelinization, dendritic proliferation and dendritic pruning. Vaughan and Kurtzberg (1992) describe a gradient of brain maturation, from subcortical to cortical areas and from primary sensory cortex to cortical association areas. This gradient is consistent with the earlier appearance of a memory system linked to subcortical brain areas (i.e., procedural/habit memory) and the more protracted development of diencephalic/cortically based memory ability (declarative/cognitive memory).

With regard to the ongoing development of declarative/cognitive memory proficiency, a variety of neuroanatomical substrates have been suggested. Bachevalier (1992) suggested that, based on studies using 2-deoxyglucose and receptor binding, the limited declarative/cognitive memory ability seen in infant monkeys is likely to be related to immaturity of inferior temporal cortical areas. DiGuilio et al. (1994)

suggested that the continued development of declarative memory throughout childhood may be related to maturation of temporal cortex as well as of diencephalic zones, including the hippocampus. Recent evidence for such a proposal comes from a study by Benes, Turtle, Khan and Farol (1994), who found increased myelin staining in specific hippocampal relay zones throughout the first and second decades of life in a sample of 164 psychiatrically normal human brain specimens. These authors state that their findings provide the first quantitative evidence of myelination continuing beyond childhood in associative cortical regions. It is possible that continued myelination translates into gradually improved processing efficiency in the hippocampus, and is at least one basis of the prolonged development seen in studies of declarative/cognitive memory.

A second major hypothesis in this study was that the relative strength of the habit and cognitive memory systems would vary as a function of age, such that cognitive memory would be more susceptible to interference from previously formed habit memory in younger children than in older children. It was predicted that the presence of previously reinforced ODT stimuli in the Complex DRT would result in poorer performance, as compared to Simple DRT performance, due to interference of prior habit memory formation with current cognitive memory. This effect was expected to be greatest for the younger children, as their cognitive memory systems were assumed to be less mature and more vulnerable to interference, in part due to their relatively immature inhibitory abilities.

The present results do fully not support this hypothesis. Instead of finding relatively poorer performance on the Complex DRT, as opposed to the Simple DRT, performance of the entire sample was more accurate on the Complex DRT. The lack of an age by condition interaction indicates that this "facilitation" effect was not different across the age-groups studied. The lack of evidence for practice effects across the two versions of the Simple DRT suggests that the increased accuracy noted on the Complex DRT was not a non-specific effect due to increased familiarity and comfort with the tasks, but rather was specifically related to the presence of previously exposed figures as recognition alternatives.

Thus, instead of making the task more difficult, use of previously exposed ODT figures appeared to make the task easier for all children. This finding was somewhat surprising. One explanation for this finding may be that the children were able to discriminate the pre-exposed foils as coming from the ODT, i.e., to form cognitive representations of the ODT stimuli, and were able to reject them on this basis. This explanation is consistent with the significant positive correlation found between the number of total correct responses on the ODT and Complex DRT performance, as well as with the positive correlation between the Complex-Simple difference score and ODT performance. Those who performed better on the ODT had a greater enhancement of performance on the Complex DRT. Although the ODT was directly modeled after, and shows a lack of developmental change similar to, the task used by Bachevalier and Mishkin (1984), which has been shown to be a valid index of habit memory, it is possible that children were able to form cognitive memories in addition to habits based on repeated exposure to the stimuli. This suggestion is consistent with Mishkin's view that the two memory systems generally act together in memory formation (Mishkin & Petri, 1984). However, it does not appear that these cognitive representations were instrumental to the performance of the ODT, since older children, who have more efficient cognitive memories, were no better than younger children on this task.

However, if the improvement in performance seen between the Simple and Complex DRTs was due to the formation of cognitive representations, one might expect that this ability would show an age effect, given the significant improvement with age seen on tasks of cognitive memory. Although the difference between total Simple DRT and Complex DRT scores did not show an age effect, the data do suggest that the ability to discriminate previously seen ODT figures improved with age. This can be seen in the fact that the Age-groups did not significantly differ from one another in the Novel trial condition, but significant differences between Age-groups were seen in both the Non-reinforced and Reinforced trial condition.

Despite the fact that no Age-group by Task interaction was found for the Simple vs. Complex DRTs, finer analyses of errors on the Complex DRT did provide some, albeit subtle, support for the prediction that younger children would tend to make more errors in which they chose previously reinforced, as opposed to previously non-reinforced, figures. The significant Age-group by Trial Condition interaction indicates that the age-groups were distinguished by the pattern of errors made, even though the previously exposed stimuli in the Complex DRT did not have a differential effect on overall task performance in the three age-groups. The separate ANOVAs examining the effect of Age-group on the Complex DRT Trial Conditions, indicated that the reinforced condition showed the most significant effect of age, followed by the non-reinforced condition, and then the novel condition. This pattern suggests that the greatest impact of age was on reinforced errors. The oldest group did not perform significantly better than youngest children in the novel condition, but did in the reinforced and non-reinforced error conditions. In addition, the reinforced error condition was the only one in which the youngest age-group also made significantly more errors than the middle age-group. This pattern suggests that some factor specific to the reinforced condition in the Complex DRT negatively impacted the performance of the youngest age group, relative to the older groups.

Examination of the separate error patterns within the age-groups provided additional support for a differential effect of previously reinforced stimuli on visual recognition performance of children of different ages. By examining differences between error rates between the novel condition (which served as a reference point), and the reinforced and non-reinforced trial conditions, patterns which distinguished the age-groups emerged. Both the middle and older age-groups made significantly fewer errors (i.e., demonstrated a facilitation in performance) in both the reinforced and non-reinforced, as opposed to the novel condition. Although the youngest group also demonstrated more accurate performance in the non-reinforced, as opposed to novel, condition, such significant improvement was not seen for this group in the reinforced condition. This indicates that the accuracy of the youngest group was not facilitated when the incorrect recognition alternative was a stimulus that had been previously reinforced in the ODT, although facilitation was present in the context of a previously presented but not reinforced ODT stimulus.

Different explanations are possible for the lack of facilitation displayed by the youngest group in the reinforced trial condition. One possibility is that the youngest group was less able to integrate their cognitive representations of the ODT stimuli with Complex DRT performance, resulting in less accurate performance in the reinforced trial condition. Their improved performance in the non-reinforced trial conditions can be explained by the fact that responding according to habit memory was consistent with accurate cognitive memory performance in these trials (i.e., they had learned not to choose the figure which was now an incorrect recognition alternative).

A second possibility is that the youngest group was able to discriminate the previously presented ODT stimuli, but had difficulty inhibiting their tendency to choose a stimulus that had previously been consistently linked with reinforcement. This group was able to inhibit responding to a previously exposed, but not reinforced, stimulus, thus displaying increased accuracy in the non-reinforced condition as compared to the novel condition. Thus, the lack of facilitation noted in the reinforced trial condition performance of the youngest age group may be due to the fact that their cognitive memory was "overridden" by previously formed habit memory.

Several researchers have emphasized the construct of inhibition in cognitive development, and the increase in inhibitory efficiency which is found in childhood development. Dempster (1992) proposed that the ability to resist interference should be considered a major factor in cognitive development, and is a process which is largely dependent on the functioning of the frontal lobe system. Both frontal lobe development and increases in inhibitory capacity have been found to occur during childhood, and researchers have proposed that development of executive functions (in which the capacity for inhibition plays a large role) is causally linked to frontal lobe development (Case, 1992; Stuss, 1992). The timing of frontal lobe structural development has been delineated, and is characterized by a sharp increase in frontal lobe size from birth through the second year of life, followed by a more gradual growth spurt between ages four and seven years. This is followed by a still slower increase in size until young adulthood, with continued myelination until the early teenage years (Dempster, 1992). Stuss (1992) noted that qualitative and quantitative changes of the brain continue into post pubertal development. Similarly, Kolb (1993) reported that cell death (i.e., pruning) continues in the human frontal lobe until approximately 16 years of age.

It may be that the relative difficulty found in younger children in accurately responding in the presence of incorrect but previously reinforced stimuli is related to immature inhibitory abilities, which in turn are likely to be related to the immaturity of their frontal lobe systems. This might have been addressed by including tasks emphasizing inhibitory abilities in the study protocol. Although speculative, data from studies of persons with frontal lobe damage also suggest a connection between Complex DRT performance and frontal lobe function. Compromise of the frontal lobes has been found to have minimal effect on overall measures of IQ. However, significant impairment is typically seen on "interference sensitive" tasks, which Dempster (1992) describes as "characterized by multiple trials, trials in which previously correct responses are no longer appropriate, stimuli that resemble one another but not all of which are appropriate at the moment, use of conflicting or misleading cues, secondary tasks, distractor activity or the interpolation of a delay prior to the response" (p.51). Several of these descriptions apply to the Complex DRT used here, particularly in the "reinforced" trials, where the child must inhibit his/her tendency to choose the stimulus that was consistently and repeatedly reinforced in the ODT, in favor of choosing the stimulus that was presented in the previous trial of the Complex DRT. However, determining whether the relative difficulty of the youngest group in the reinforced trial condition of the Complex DRT is due to difficulty recognizing ODT stimuli or difficulty inhibiting previously reinforced responses requires additional research. This question might be addressed by developing a test of recognition memory for the ODT stimuli, to determine whether children are able to recognize ODT stimuli and to assess potential age differences in this ability.

There were no significant relationships among the experimental memory measures and reading ability or IQ, once alpha levels were controlled for the use of multiple correlations. The lack of significant relationships found between the memory measures and the verbal abilities assessed by the WRAT-R Reading Subtest and the Vocabulary Subtest of the KBIT support the proposal that performance on the experimental tasks is relatively independent of language skills. In addition, it appears that performance on the habit and cognitive memory tasks is generally independent of intelligence. The pattern of significant trends consistently appearing in the relationship between IQ measures and performance on the Simple DRT #1, however, is probably not due to chance, and may be reflect a relationship between intelligence and novel problem solving, as this was the first test administered.

No significant relationships were found between performance on the memory measures and attentional ability as assessed by CPT performance, once age-related variance was controlled for. The lack of a significant correlation between CPT performance and scores on the memory measures may be due to the fact that the subjects were cued upon stimulus presentation in the memory tasks, thus decreasing intersubject variability due to attentional factors. With regard to the relationship between habit and cognitive memory tasks and behavioral rating scale measures, only the correlation between total ODT performance and the Conduct Problems factor from the CPQ remained significant, once alpha levels were controlled due to multiple correlations. Better performance on a test of habit memory was associated with a lower level of conduct problems. It may be that more efficient encoding of response-reward contingencies leads to better ODT performance as well as to fewer behavioral difficulties. However, since this was only one of multiple correlations and may represent a chance finding, firm conclusions are not possible. The overall findings suggest that the abilities assessed by the habit and cognitive memory tasks bear little relationship to normal children's attentional or behavioral functioning, at least within the sample of children used in this study. It is possible that, in a referred sample, characterized by more variability on the behavioral and CPT measures, significant relationships between these measures and the memory tasks would be found.

Examination of the effects of task sequence suggest that the administration of the Simple DRT #2 between the ODT and Complex DRT resulted in lower overall Complex DRT performance across all three age groups. When performance within the trial conditions of the Complex DRT was examined separately, performance on Novel trials was found to be unrelated to task order across the three age groups, while the number of reinforced and non-reinforced errors was increased when the Simple DRT #2 was placed between the ODT and the Complex DRT. This finding is probably due to an interference effect created by exposure to similar visual figures, which made discrimination of previously exposed ODT stimuli from novel stimuli more difficult for the children, regardless of age.

The conclusions of this study are limited by the use of a cross-sectional design, in that differences found between age groups may be related to the unique experiences of that group, rather than to developmental changes per se (cohort effect). In addition, the conclusion that habit memory reaches its mature level by early childhood must be tentative, in that children older than 14.5 years were not studied and it is possible that further development of habit memory proceeds after this age. Finally, it is important to be cautious when ascribing functions to tasks in humans based on findings with animals. The validity of delayed response tests in human subjects has been supported (e.g., Squire, Zola-Morgan & Chen, 1988). The ODT is well validated in research with monkeys, but the degree to which it assesses the process in humans is not clear, particularly when easily verbalizable stimuli are used. In this study, an attempt was made to control for the effects of language processes, which show significant effects of development, by using stimuli which were non-verbalizable. Additionally, it is simplistic to assume that a given test measures any one particular function in humans. Despite these cautions, the gradual rate of learning and lack of age differences found on the ODT support the contention that this tasks assesses a non-cognitive retention ability in children.

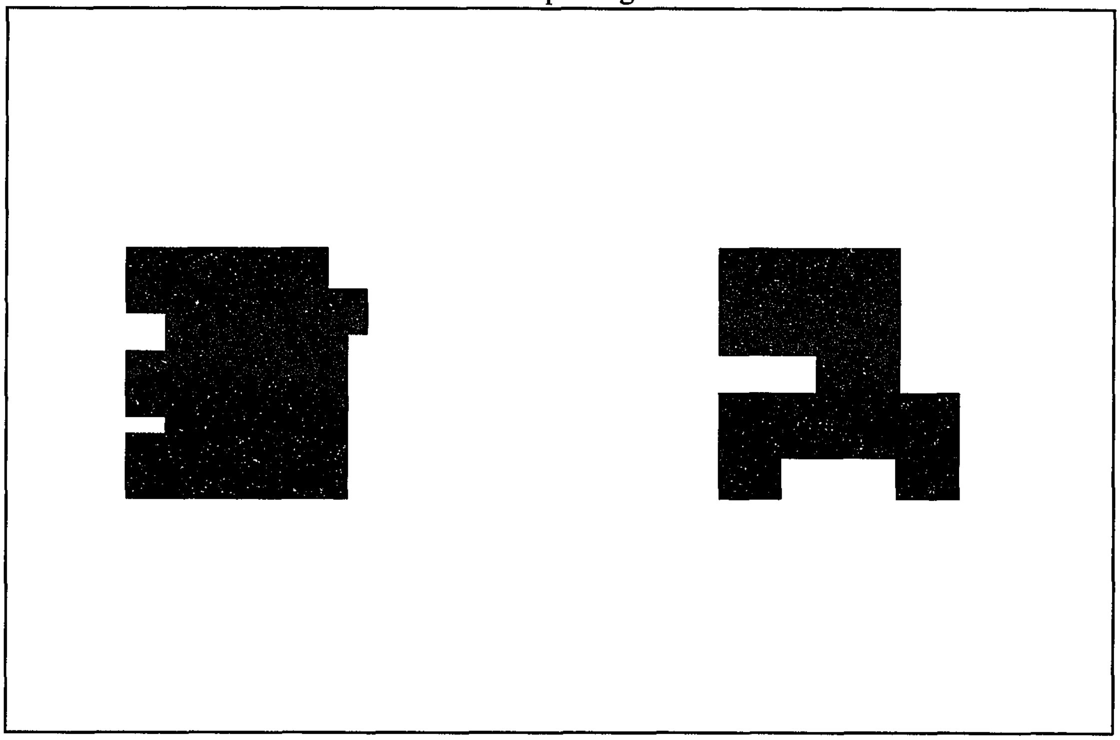
Future directions for research include the examination of habit and cognitive memory abilities in older adolescents/young adults as well as elderly subjects, in order to trace these processes across the lifespan. In addition, it would be of interest to study habit and cognitive memory in persons with head injuries. Although this population is known to have memory deficits on traditional declarative memory tasks (Lezak, 1983), one might predict relative sparing of habit formation in persons with brain damage restricted to cortical areas, while both memory systems might be compromised in persons who have suffered damage to both cortical and subcortical areas.

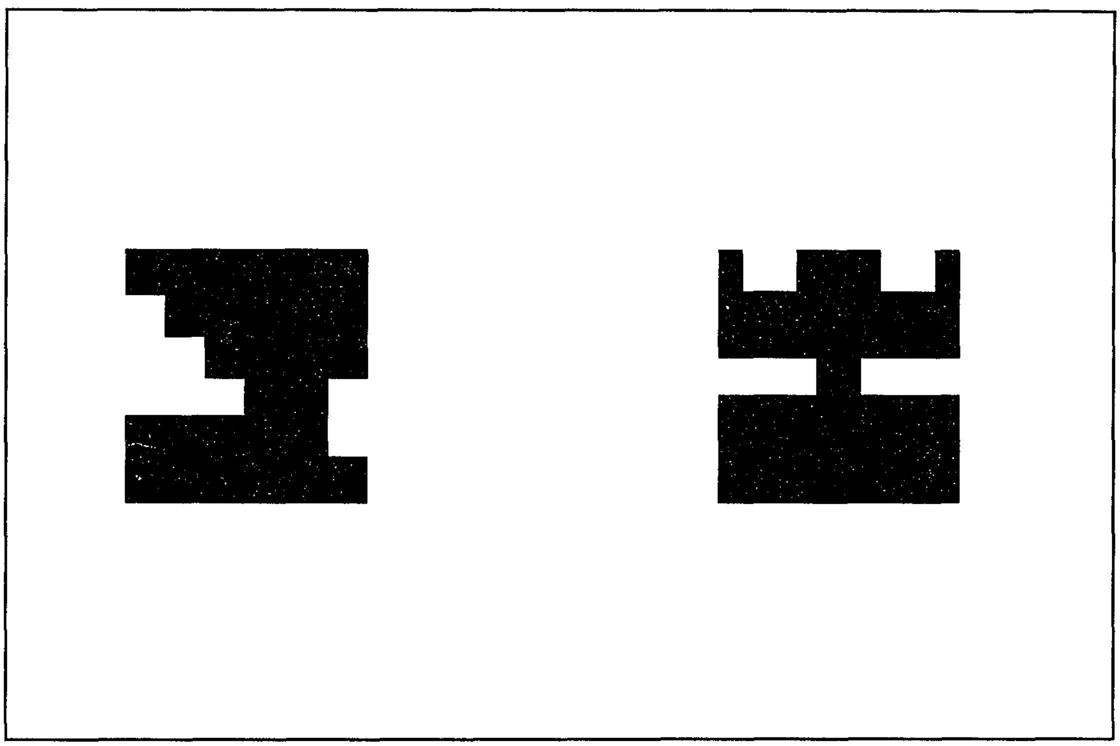
Another population in which examination of habit and cognitive memory performance would be of interest is children diagnosed with Attention-deficit Hyperactivity Disorder (ADHD). Some authors have suggested that children with ADHD are characterized by an abnormal responsivity to reward (Douglas, 1983), such that they show greater decrements in performance when consistent reinforcement is not provided. This proposed overresponsivity to reward has been related to their difficulty in tasks which require them to delay their responses (Douglas, 1983). Research on memory abilities in ADHD suggests that basic memory processes are intact in children with this disorder. Douglas and Benezra (1990) noted that non-learning disabled

ADDH boys (diagnosed according to DSM-III criteria) show relatively normal memory performance when moderate effort and strategy demands are operative, but showed deficits on tasks requiring increased organization, deliberate rehearsal, sustained strategic effort and careful consideration of response alternatives. Similarly, Borcherding et al. (1988) found that non-learning disabled ADHD boys showed normal performance on tasks assessing "automatic" memory processes, such as word frequency estimation and recognition, but were poorer on effortful memory tasks such as free recall. Thus, one might expect ADHD children to perform normally on tests of habit memory, such as the ODT, but to have relative difficulty on cognitive memory tasks, such as the Simple and Complex DRT, which require more effortful processing and efficient inhibition.

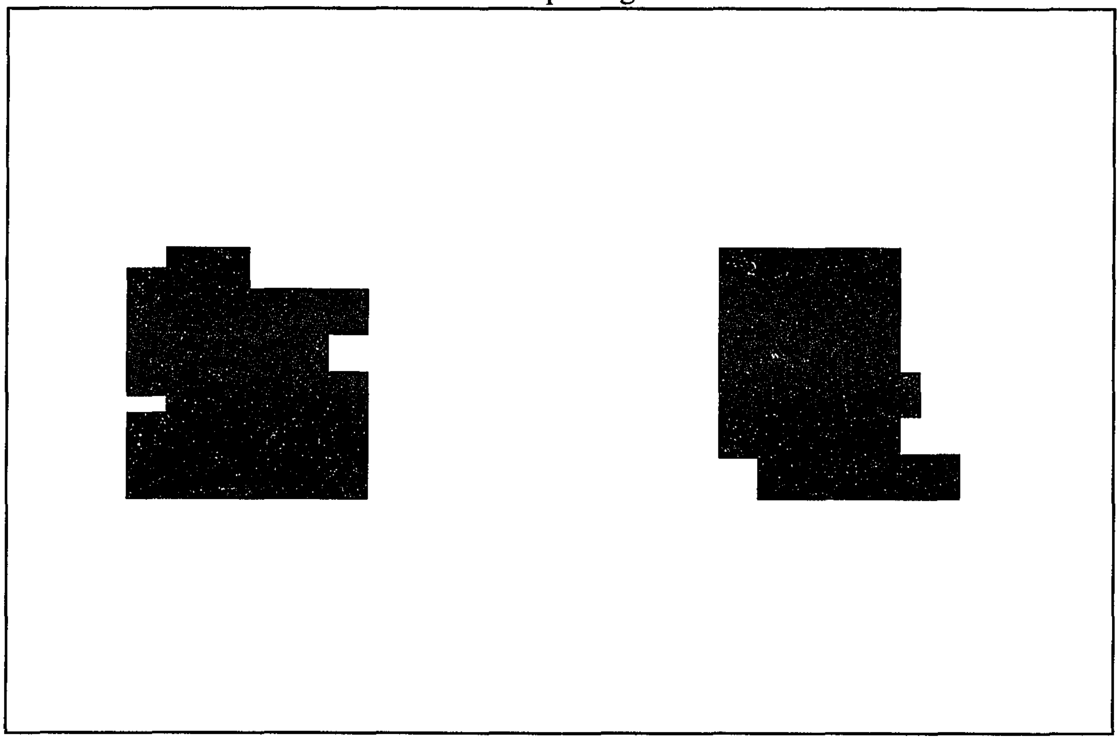
In summary, the results of this study suggest that visual habit formation reaches its mature level early in childhood, whereas cognitive memory, as assessed by visual recognition, matures over a longer period of development. Habit and cognitive memory were found to be relatively independent processes, although evidence was found for their integration under certain task conditions. In addition, the results indicated that younger children seem to have difficulty inhibiting responses based in prior habit memory in the context of different reinforcement contingencies.

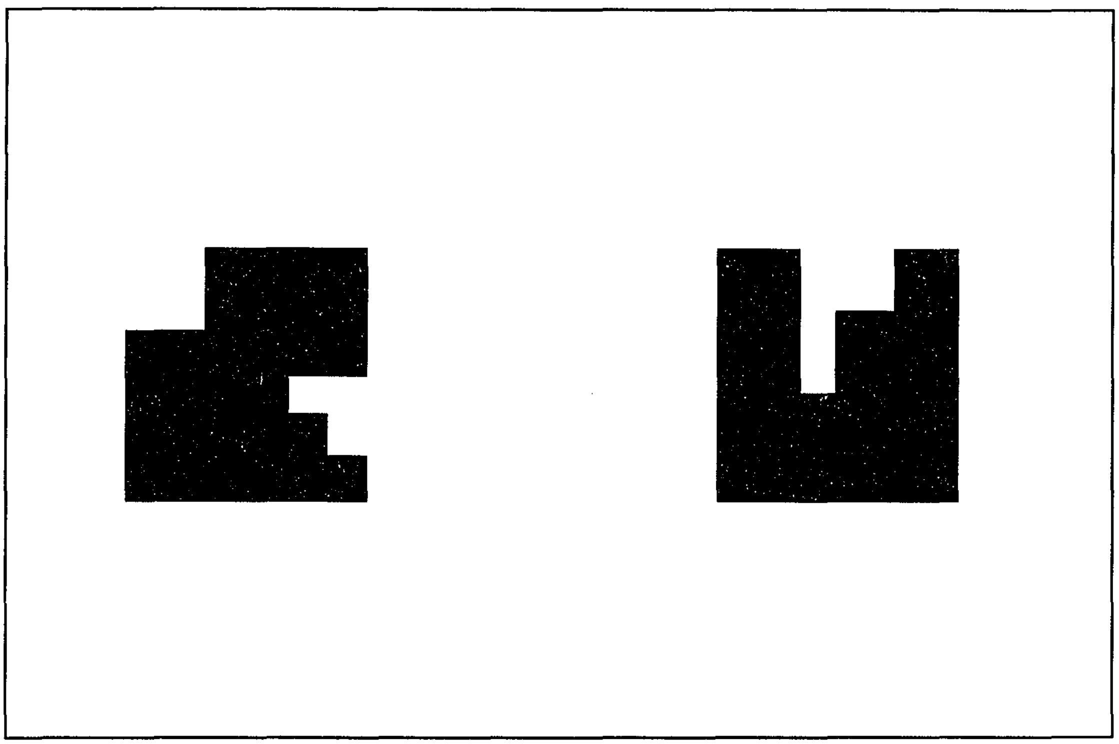
Example Figures





Example Figures





Appendix B

Instructions for Memory Tasks

Object Discrimination Test:

"This game is like a guessing game. You will see pairs of shapes come up on the computer screen. Try to guess which one is the right one, by pointing to it. When you pick the right one, the computer will play a song, and I will put a bead in the jar. When you pick the wrong one, the computer won't play a song and you won't get a bead. I will also tell you whether you are right or wrong. Later you will get to trade in all the beads you earn for a toy. Don't worry when you get some wrong in this game, everybody does. Just try to guess which shape is the right one as quickly as you can. Any questions? Okay, let's try some for practice."

Simple and Complex Delayed Response Tests:

"In this game, the first thing you will see is a list of shapes come up on the computer screen, one at a time. After you see some shapes one at a time, you will see shapes come up two at a time. When you see the shapes two at a time, point to the shape that you just saw before, by itself. When you pick the right one, the computer will play a song, and I will put a bead in the jar. When you pick the wrong one, the computer won't play a song and I won't put a bead in the jar. I will also tell you whether you are right or wrong. Try to point at quickly as you can, but try to get the right one. Don't worry if you get some wrong, everybody does. Any questions? Okay, let's try some for practice." (Children were also prompted during the task. When viewing presentation shapes, the experimenter said "look at this one", and when recognition pairs were presented, the experimenter said "Which one did you just see, by itself ?")

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