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IMPLICIT PROCESSING - A DEVELOPMENTAL STUDY OF THE EFFECT OF INSTRUCTIONS, UNDERLYING STRUCTURE AND MATERIALS

by

ARMONIT ROTER

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Abstract

IMPLICIT PROCESSING - A DEVELOPMENTAL STUDY OF THE EFFECT OF INSTRUCTIONS, UNDERLYING STRUCTURE AND MATERIALS

by

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Recent research in implicit learning and automatic processing in adults has shown that adults can abstract some knowledge of complex underlying structure from instances of the structure. In the present study two experiments were carried out to learn about implicit processes in children. Implicit processes are inductive cognitive activities which enable humans to abstract complex knowledge from the environment. The knowledge acquired is tacit,that is, it guides the subject's behavior without the subject being necessarily aware of the knowledge and often, of its very existence.

In Experiment 1 adults and children (age 5 to 10) were exposed to exemplars of an artificial grammar composed of geometric shapes and were required to learn these exemplars by reconstructing them from memory. A recognition task was used in order to test whether the subjects acquired some knowledge of the grammar in addition to a specific memeory of the learning set.

The performance of all the subjects in the recognition task exhibited definite evidence of some degree of abstraction of the underlying grammar. In addition, there were no significant differences between the adults and the children. These results indicate that for this type of task, children as young as five already possess implicit processes very similar to the processes available to adults.

In Experiment 2 the subjects were children from three age groups (5-7, 9-11, and 12-14). The methodology used was very similar to the methodology of Experiment 1. In addition, three manipulations were carried out to learn more about three issues raised in recent implicit learning research with adults: (1) the effect of predisposition; (2) specific vs. abstract knowledge; and (3) the effect of materials.

The results of Experiment 2 replicated the results of Experiment 1 in that all three age groups abstracted some knowledge of the underlying grammar and there were no significant age differences. The results of the three manipulations were mixed: (1) it was not possible to ascertain the effect of a change in predisposition; (2) the effect of manipulating the structure in order to compare specific and abstract knowledge was highly significant; (3) the effect of manipulating the materials used in producing the the exemplars of the grammar was not strong but was in the expected direction.

ACKNOWLEDGEMENT

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To Yigal, Eran, Tali and Erez, my family who stood by me throughout the long, demanding effort.

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INTRODUCTION

The notion of unconscious, or implicit cognitive processes, has been appearing and disappearing in different guises in the psychological and philosophical literature since antiquity. The idea that cognitive processing can occur outside of awareness is as old as humans thinking about thinking (for example see Ellenberg's, 1970 overview).

The concept of implicit processes is multifaceted. The nomenclature used in current works (e.g. automatic processes, unconscious processes, intuitions, tacit knowledge) reflect not mere semantic differences but rather the diverse aspects of the concept. There are only a handful of studies and models dealing with implicit processes. Each applies a label best reflecting the aspect of implicit processes relevant to a particular model proposed and the issue it is attempting to address. There is no single theory or model that encompasses all aspects of the notion.

The current works which influenced the present study derive from three theoretical sources: (1) Theories coming out of the information processing tradition - these theories emphasize the automatic aspects of the processing. (2) Theories coming from a learning theory and/ or psycholinguistic tradition - these studies, using an artificial language acqusition paradigm, emphasize the nonexplicit aspects of processing. (3) Developmental theories which do not deal directly with implicit processes but are significant for any comprehensive theory of implicit processing.

The aim of this research is to present evidence for the existence of implicit abstraction processes in children and to demonstrate that these processes can be studied experimentally. This research is primarily focused on how children go about abstracting complex information from instances generated from an underlying rule system or 'grammar'. It is hypothesized that children posses implicit cognitive abstraction processes very similar to those demonstrated for adult populations by Reber and his associates in their research (Reber, 1967, 1969, 1976; Reber & Allen, 1978; Reber, Kassin, Lewis & Cantor, 1980). Moreover, an attempt is made to detect developmentally meaningful modifications in the quality of these implicit processes between different age groups.

The present study addresses from a developmental perspective three issues raised in the current implicit processing research: (1) the effect of predisposition; (2) the relation betweeen analogical and abstract implicit processes; (3) the effect of context.

A. Definitions

A.1. Tacit knowledge

One of the basic assumptions underlying this thesis is that any psychological understanding of knowledge and its acquisition must take into account the tacit nature of most of our knowledge.

Polanyi (1958, 1966, 1967) introduced the concept of "tacit knowledge" in order to distinguish between two species of knowledge - tacit and explicit. Explicit knowledge is that knowledge which we can speak about, formalize and which becomes, according to Polanyi, the reversible operations in the Piagetian sense (Piaget, 1960; Polanyi, 1958, p. 74-77). On the other hand, tacit knowledge is knowledge about which we cannot speak, of which we are unaware and probably will never be able to fully explicate formally. Tacit knowledge is the source of all knowledge. Moreover, the process of achieving explicit thought, including language, is itself a tacit operation. As Polanyi (1967) states:

> ...use of language is a tacit operation, both in our spoken language and in our understanding of it when spoken by others. The same applies to all other explicit thought; it can be developed and understood only by a tacit operation and it is thus based throughout on tacit knowing. All knowledge is either tacit or rooted in tacit knowing. (p. 42)

Polanyi's thesis has two consequences: first, that much of the research done in perception, cognition, concept learning, problem solving etc., actually deals with the tacit-explicit conversion, (see Franks, 1974 and Turvey, 1974 for a similar position and some examples) and second that developmentally tacit knowledge is prior to explicit knowledge.

A.2. Implicit processes

Implicit processes are inductive cognitive activities which enable humans to abstract complex knowledge from the environment. The knowledge aquired with these processes is tacit; that is, it guides the subjects' behavior in various situations without the subject being aware of the nature of this knowledge and, often, of its very existence.

A.3. Prerequisite conditions for experiments on implicit processes

In order to study these processes experimentally three conditions must be met: (1) The subjects must be attending actively to the instances generated by an underlying rule system. (2) The rule system that generates the instances must be complex in the sense that any explicit analytical process that the subjects may possess (such as hypothesis testing or logical analysis) would be inadequate for discovering the rule system. (3) The tasks for testing whether these processes are activated should be sensitive to the existence of acquired knowledge of the underlying structure, without requiring the subject to explicate or verbalize this knowledge in any way.

B. Review of existing theories

B.1. Information processing theories - automatic processes

The basic tenet proposed by information processing (IP) theories is that there is a limited capacity central processor (CP) that carries out and controls the major information processing tasks. More recent research in IP suggests that additional processes exist which occur outside of the central processor (Hasher & Zacks, 1979; Posner & Snyder, 1975; Posner & Warren, 1972; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). These additional processes do not require the use of the limited capacity central processor and therefore, can occur simultaneously with other processes which involve the CP. Moreover, they are automatic, i.e. not under the control of the CP.

These theories appear as part of IP models dealing with memory and attention. As such, they do not deal directly with the issue of knowledge acquisition, though some extrapolations to this issue are possible.

Hasher & Zacks's theory of automatic and effortful processing

Probably the most developed formulation of an automatic processing theory offered by IP theorists is presented by Hasher & Zacks (1979).

Hasher & Zacks base their model on two assumptions taken from Kahneman's (1973) model of attention. These assumptions are that: (1) There exists a limited capacity attentional mechanism. The actual capacity available varies with age, individual, and emotional state, and it interacts with encoding demands and memorial processes; (2) There is a continuum of attentional requirements among encoding processes. At the one extreme are effortful processes and at the other there are automatic processes.

Effortful processes are, in the Hasher & Zacks model, analogues to Posner & Snyder's (1975) "conscious strategies". They require effort in that they engage the central capacity processor and thus limit the ability to engage simultaneously with other effortful processes. Their efficiency increases with practice, their use is voluntary and often occurs only with specific instruction. According to Hasher & Zacks, we are usually aware of the effortful processing mechanisms that are activated. The awareness (knowledge of) and use of the effortful memory operations develop hand in hand. Effortful processes exhibit a wide range of individual differences. Examples of effortful processes are: the use of imagery for remembering, organization and clustering, rehearsal, and other mnemonic strategies.

The automatic processes are activated whenever a person is attending to input and these processes enable the information about attributes of an event to enter long-term memory without any draining of the limited capacity mechanism. Hasher & Zacks (1979) list six characteristics of automatic processes: (1) they operate continually whenever information is at the focus of attention; (2) they do not require awareness or intentionality; (3) they require a minimum amount of attention, thus they are not disrupted by high energy situations like stress; (4) once a process is automatized it cannot be improved upon by adding practice or feedback; (5) the operation of automatic processes cannot be willfully inhibited; (6) knowledge gained by automatic processes is accessible to consciousness and can be used by the person for various cognitive functions.

Hasher & Zacks extend the concept by distinguishing between two types of automatic processes: innate, prewired processes and learned or practiced processes. The hereditary automatic processes encode such things as frequencies, spatial location, and time of events. These processes play an important role in achieving a cognitive orientation in the routine flow of events of our environment. These processes require minimal experience and are widely shared by all humans. They are not influenced by age, culture, education, intelligence, emotional states or illness. On the other hand, the "learned" automatic processes share some but not all of the attributes of the innate processes. The learned processes are created through large amounts of practice. Once they are formed they are very similar to automatic processes in all the characteristics stated above except for their sensitivity to stressful circumstances. As an example of a learned automatic process, Hasher & Zacks give the encoding of the meaning of words from their written presentation. Since these processes are formed through extensive personal experience, individuals vary substantially in their repertoire of "learned" automatic processes.

B.2. Learning and psycholinguistic approach

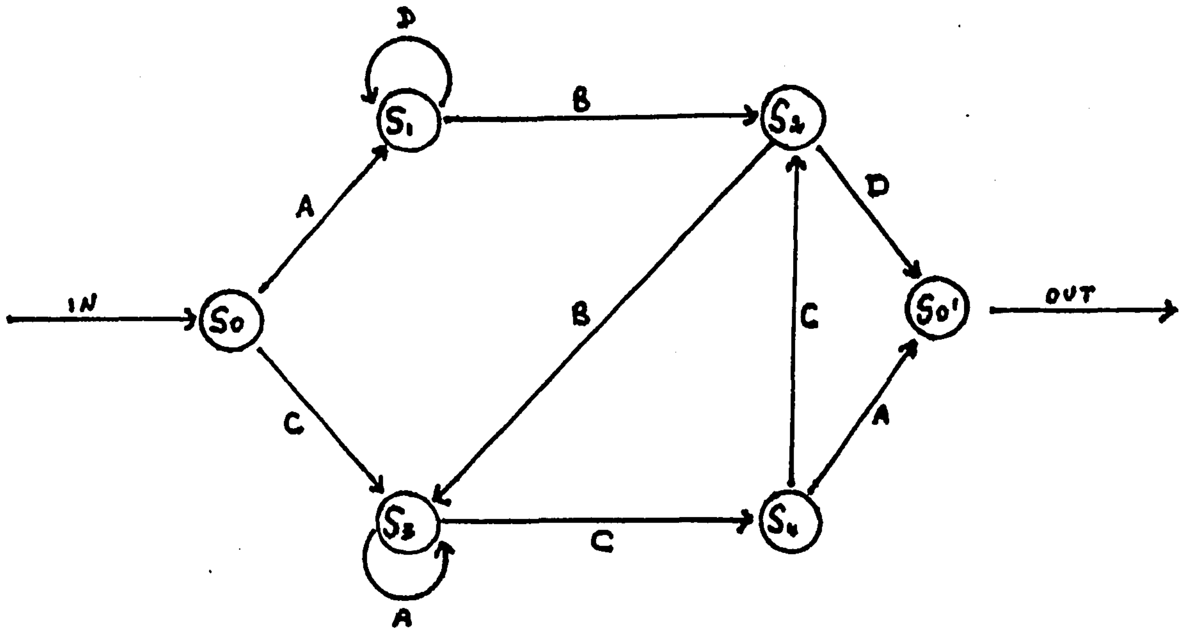
As a result of the controversy on language acquisition between Skinner's behavioristic position and Chomsky's psycholinguistic approach, there was a renewed interest in how humans acquire complex rule systems. George Miller (1958) proposed the use of a finite-state grammar in an artificial language learning experiment in an attempt to find out more about how we go about learning the rules of an underlying abstract structure.

A finite state grammar is composed of a definite number of internal states, where a transition from one state to another is marked by an emission of a symbol. Sequences (strings) of symbols of various lengths are thus produced by following the permissible shifts from state to state. Each particular finite state grammar produces its own set of permissible symbol strings of any specified length (see Figure 1 - for

Figure 1

Schematic diagram of the finite-state grammar

used to generate the sequences



Simple Stimuli			Meaningful Stimuli		
A =		yellow	A =		yellow
B =		blue	B =		blue
C =		green	C =		green
d =		red	D =		red

Figure 2

All possible sequences of lengths of 3 to 7 shapes generated from the finite state grammar shown in Figure 1 and their distribution in Experiment 1 and Experiment 2

Exper. 1*	Exper. 2*	Sequence
B	B	△ □ ○
C	C	◇ ◇ △
A	A	△ ○ □ ○
B	B	◇ △ ◇ △
C	C	◇ ◇ ◇ ○
A	A	△ □ □ ◇ △
-	B	△ ○ ○ □ ○
B	A	◇ △ △ ◇ △
C	C	◇ △ ◇ ◇ ○
A	A	△ □ □ △ ◇ △
B	B	△ ○ □ □ ◇ △
B	B	△ ○ ○ ○ □ ○
C	C	△ □ □ ◇ ◇ ○
-	C	◇ △ △ △ ◇ △
C	C	◇ ◇ ◇ □ ◇ △
A	B	◇ △ △ ◇ ◇ ○
A	A	△ ○ ○ ○ ○ □ ○
-	-	△ ○ ○ □ □ ◇ △
A	C	△ ○ □ □ △ ◇ △
B	B	△ □ □ △ △ ◇ △
B	B	△ ○ □ □ ◇ ◇ ○
C	C	△ □ □ △ ◇ ◇ ○
C	C	◇ △ △ △ △ ◇ △
A	B	◇ ◇ ◇ □ ◇ ◇ ○
B	B	◇ △ ◇ ◇ □ ◇ △
-	-	◇ ◇ ◇ □ △ ◇ △
C	C	◇ △ △ △ ◇ ◇ ○

* Distribution of sequences in part I and part II of each experiment.

A - Used in part I of the experiment.
B - Used in part II of the experiment.
C - Used in both parts of the experiment.
\- - Not used.

an example of a finite-state grammar and Figure 2 for a list of all the possible permissible "grammatical" strings of a specified length.).

Miller (1967) eventually abandoned the use of finite-state grammars on the grounds that such complex rule systems "... were far too difficult for an afternoon in the laboratory." (p. 144). Other researchers adopted a variety of rule systems for their artificial language acquisition studies with different age groups (see Lewis, 1975 for a review).

Reber's implicit learning theory

Reber (1967, 1969) adopted Miller's use of the finite-state grammar as the underlying rule system in an artificial language acquisition experiment. But instead of testing the subject's ability to formalize and explicate the rule system of the finite-state grammar, the subject was asked to perform a "grammaticality" judgment, i.e., to decide whether new symbol strings shown in the second phase of the experiment conform or do not conform with the "grammar" underlying the strings seen in the first phase. Hence these studies require that the subject act on his newly acquired knowledge rather than try to verbalize it.

From this and subsequent research done by Reber and his associates emerged the first Implicit Learning Theory (ILT). These studies serve as the starting point for this research; therefore, it is important to summarize the basic tenents of the ILT as well as the research methodology.

The basic paradigm of this type of experiment requires that it be conducted in two parts. In Part I - the acquisition stage - the subject is exposed to (learns, memorizes) a set of exemplars generated from the grammar. Subjects are not told to look for any underlying rule system or "grammar". In Part II - the testing phase - the subject's knowledge of the grammar is tested by requiring the subject to make a "grammaticality" judgment on a set of exemplars which includes: "old grammatical" exemplars (instances seen in Part I); "new grammatical" exemplars (instances generated from the same finite-state grammar as the learning set but not seen before by the subject); "new nongrammatical" exemplars (generated by violating the grammar).

The results of these studies show that even though initially subjects are taken aback by the unexpected request for grammaticality judgments, their 'hit rate' is significantly above chance. Moreover, Reber (1969) has shown that if the subjects are switched to a new set of symbols with the same underlying grammar there is a positive transfer. On the other hand, if the underlying grammar is changed, regardless of any change in the actual symbols used, there is a negative transfer. Reber (1976) characterized implicit learning as a "process whereby a subject becomes sensitive to the structure inherent in a complex array by developing (implicitly) a conceptual model which reflects the structure to some degree." (p. 88)

ILT raises a number of issues with far reaching implications. The first deals with the role of implicit learning in knowledge acquisition.

According to ILT, implicit learning plays an important role in acquisition of language and other complex systems: "complex structures, such as those underlying language, socialization, perception and sophisticated games are acquired implicitly and unconsciously." (Reber et al, 1980). In 1985 Reber, Allen & Regan went even further in stating: "Essentially every complex knowledge acquisition task is accomplished largely in the absence of conscious control." (p. 16).

The Reber et al, 1985 proposition is provocative. From the IP models it follows that, except for some basic orienting duties of automatic "innate" processes, the automatic "learned" processes were originally conscious, effortful processes that became automatized and routinized through practice. If we are to accept that these automatic processes are also applied in complex rule acquisition then these processes as well as the knowledge acquired are essentially (or at least originally) conscious. In other words, the IP position can be interpreted as directly opposing the ILT position (see Dulany, Carlson & Dewey, 1985 and Reber, et al, 1985 for a discussion of this issue).

At this point, the issue is still open to debate. Developmentally, however, this is a fundamental issue. Therefore, one of the most fruitful ways of learning more about it should be through developmental research, hence the approach of this study. We will return to this issue when we discuss the Pendulum Theory of Nelson & Nelson (1978).

The second issue raised by ILT revolves around the nature of the knowledge acquired. According to ILT the knowledge acquired through implicit learning is an abstract representation of the "deep structured relations" in the stimulus environment. The relationship between the representation and the environment is undistorted: "the form of the mental code must be isomorphic with that environment." (Reber & Lewis, 1977). As Reber & Glick (1978, man.) characterize the abstract knowledge acquired it is a veridical representation of the invariance of the subject's structured environment. Thus, according to ILT, errors made by subjects are a result of insufficient knowledge ("incomplete structures") not of "nonrepresentative" information; even though the form of the representation may be very different from the experimenter's representation (Reber, et al, 1984).

On the nature of the implicit learning processes, Reber states that they are induction processes which can abstract underlying relations from instances. Reber & Lewis (1977) describe the process as a "naturally occurring, unconscious cognitive act, an automatic process of a human mind operating in any complex environment." There are, according to ILT, at least two distinctive components of the acquisition process:

> First, there is a general differentiation-like process similar to that proposed by Gibson & Gibson (1955) and others (e.g., Mace, 1974; Shaw & McIntyre, 1974). According to this view the most salient cues, the ones with the highest invariances are abstracted out first with the less salient, less invariant relations following. ... Second, the characterization of implicit learning also requires a Gestalt-like, global apprehension process whereby a configurational representation of the system is set up.
> (Reber & Lewis, 1977, p. 356).

The relationship between these two components is still unspecified in ILT. One approach may be to view these components as two sides of the same coin, i.e., a complementary relationship similar to the relation between assimilation and accommodation in the Piagetian theory (Piaget, 1970 pp. 708, 709).

Another issue that motivates the ILT research is the attempt to delimit boundaries and conditions for the activation of implicit processes. Reber & Allen (1978) argue for a functionalist approach to cognitive processing and knowledge acquisition. According to this approach, humans have at their disposal a wide range of procedures for information processing ranging from explicit (analytical) to implicit (abstract and analogical) processing. The particular process activated in a specified situation depends on the task and the materials at hand, the repertoire of processes available to the subject as well as his past experience with these processes and tasks. The issue will be examined in greater depth in context of the results of the ILT studies presented in the following section (part C).

B.3. Developmental theories

Developmental theories do not deal explicitly with the issue of implicit processes. A few deal with questions closely related to specific aspects of implicit processes. In order to get an idea of what developmental theories have to contribute to implicit processing theory, a short summary will be presented of some developmental approaches which have bearing on various aspects of implicit processing. Four examples will be given: Piaget's use of the concept of cognizance; the notion of involuntary memory in developmental memory research; Fischbein's ideas on intuition and Nelson & Nelson's Cognitive Pendulum Theory.

B.3.1. Cognizance, involuntary memory and intuitions

The unconscious aspect of cognitive processing is addressed by Piaget in his more recent work dealing with the problem of "cognizance". According to Piaget (1976) cognizance - coming into consciousness - is achieved through processes of conceptualization and reconstruction. He claims that, initially, action schemes as well as operatory schemes are unconscious. Only at the stage of reflected abstraction (formal operations) is cognizance extended to a 'reflexion' of thought on itself. Studies carried out in Geneva show that there is always a lag between the child's ability to act on and to solve problems and his conscious knowledge (formalization) (Piaget, 1976, 1978).

Research on the development of memory raises another aspect of implicit processes - the control the subject has over his own processing. Taking an IP perspective, the researchers in memory development speak of involuntary memory (e.g., Brown, 1979) or automatic memory processes (Naus & Halasz, 1979). For example, Naus & Halasz contrast deliberate and automatic memory. According to their model, deliberate mnemonic strategies show significant developmental change, require attention, are unaffected by the stimulus environment, are sometimes conscious and, of course, are voluntary and planned. On the other hand, automatic memory processes are involuntary, unplanned, elicited by the stimulus environment in relation to available semantic memory and unconscious. In addition they do not require attention and exhibit few developmental trends.

A very different approach is taken by Fischbein (man., 1978, 1980). His research is based on the application of a Piagetian model to the teaching of mathematical concepts. In his work Fischbein raises the tantalizing notion of intuitions. The concept of intuitions is based on Polanyi's concept of "tacit knowledge". The developmental model of intuitions which Fischbein proposes emphasizes the importance of reaching a compatible equilibrium between our intuitive (implicit) knowledge and our analytic, formal (explicit) knowledge and functioning.

B.3.2. Nelson & Nelson's cognitive pendulum theory

Nelson & Nelson (1978) offer a novel model of cognitive development - the Cognitive Pendulum Theory (CPT). They reject the common notion of a linear (improvement) account of develpoment in favor of a 'pendulum' model of development. A pendulum model proposes that as a child acquires knowledge there are shifts back and forth in the type and in the quality of his processing. [See also Strauss (1982) whose U shaped behavioral growth model takes a similar approach].

The two types of processing that the child fluctuates between are characterized by the CPT as: on the one extreme - broad, flexible, open and context sensitive processing versus on the other extreme - narrow, rigid, restricted, context bound processing. Developmentally the flexible period of processing precedes a rigid, restrictive processing.

According to their model there are two areas where this oscillation in processing can be found. The first domain is in the longitudinal view of the acquisition of any specific systematic complex body of knowledge. The second is in the quality of the processing exhibited by children at different cognitive levels.

The two areas are only partially independent in the sense that being at a certain stage (type of processing) in the domain of system acquisition is modulated by the mode (quality of processing) that is characteristic of the particular cognitive level. For example: a child can be in the initial flexible stage of acquisition in relation to a specific system, and at the same time, from the cognitive level point of view, the child's processing has a rigid quality. Compare this child to another child who is at the same processing stage in relation to the acqusition of the specified system but is in a open mode of processing as determined by his cognitive level. Both children are in a flexible stage of acquisition of the system, yet the second child will be <u>relatively</u> more flexible in his processing than the first child, due to the differential effect of the cognitive level.

Nelson & Nelson's CPT does not touch upon the subject of implicit processing. Nevertheless, an implicit/explicit processing interpretation can be imported into the CPT. The conversion can be carried out in a straightforward manner: the flexibility of processing can be interpreted as a result of the activation of implicit processes and the more rigid and literal type of the processing can be interpreted as a result of the activation of explicit analytical processes. [This interpretation is acceptable to at least one of the Nelsons (personal communication).]

If this interpretation of the CPT is reasonable, it is possible to predict that the acquisition of complex knowledge goes through a number of stages. At the first stage of acquisition only implicit processes are activated, resulting in broad, general rules which form the rudimentary tacit knowledge base. At this point, the knowledge can be applied flexibly as long as the task does not require any verbalization of it. At the second stage, explicit processing of the tacit knowledge begins. The child starts to formalize and analyze, formulating many specific rules which he adheres to literally. In the third stage, both the implicit and explicit processing are activated in concert to achieve a complete, integrated understanding.

In addition, the quality of the implicit and explicit processes available, at any age, is modulated by the cognitive level that the child has achieved. At the preschool age, the children's processing is generally flexible. Between the ages of seven and twelve there is a qualitative shift in children's processing and it becomes more context-bound and rigid. In adolescence there is a renewed openness and flexibility, though, at this stage the processes are qualitatively different from the flexible processes of the preschooler.

B.4. Summary of theories

Three very diverse theoretical sources have been presented in this section which speculate on or allude to implicit processes. These theories raise a number of intriguing ideas for formulating a developmental theory of implicit processes:

(1) The information processing theories draw attention to the need for postulating the existence of automatic processes. Hasher & Zacks extend the IP position and suggest that there are two types of automatic processes - innate and learned. According to Hasher & Zacks, only the learned automatic processes undergo developmental changes.

(2) Reber & his associates are the first to show that implicit learning of complex underlying structure can be demonstrated empirically. They claim that implicit learning results in veridical knowledge and that implicit learning plays a significant role in the acquisition of language, social norms, sophisticated games and other complex knowledge. They offer a functionalist approach to explain the diversity of variables that effect the activation and nature of implicit processing.

(3) Developmental theories suggest that each aspect of implicit processing should be examined from a developmental perspective: Piaget on the unconscious aspect; Naus & Halasz on the involuntary aspect; and Fischbein on the intuitive aspect.

Nelson & Nelson offer a provocative model which can be interpreted as the first rudimentary theory of the development of implicit processes as well as a theory of the developmental relationship between implicit and analytical (explicit) processes in the acquisiton of complex systems of knowledge.

C. Review of research and related issues

As stated before, Reber and his associates have carried out a number of studies which attempt to clarify the boundaries and conditions for the activation of implicit processes. The research presented in this thesis was designed to address some of their basic findings from a developmental perspective and therefore it is important to first review the pertinent data.

C.1. Explicit versus implicit predisposition

In 1976 Reber reported a seemingly surprising result in a grammar learning experiment. Subjects instructed before the learning phase of the experiment to look for an underlying regularity in the strings of symbols, performed worse than subjects given neutral instructions. The interpretation of these results offered by Reber (1976) was that the explicit stance created by the instructions seemed to interfere with the subjects' abstraction of the grammar. Brooks (1978) replicated Reber's study getting essentially the same results.

In order to better understand these results two manipulations were carried out (Lewis, 1975; Reber, Kassin, Lewis & Cantor, 1980). The first manipulation consisted of varying the salience of the rule structure (grammar). The salience of the rule structure is the degree to which the underlying structure was made more or less obvious by manipulating the order of presentation of the strings in the acquisition part of the experiment. When salience was low (random order of presentation) 'explicit' instructions were detrimental, that is the performance of the implicit - neutral - instruction group was better than that of the explicit group. On the other hand, when salience was high, the explicit instructions were beneficial to this group and they performed better than the implicit group with the same highly salient presentation.

The second manipulation varied the timing of explicit training. Explicit training must be distinguished from explicit instructions. Explicit training involved presenting subjects with the actual underlying rule system used and teaching them how exemplars are derived from this system. Explicit instructions, as stated before, merely make the subjects explicitly aware of the existence of an underlying structure which generates the exemplars. Lewis (1975) showed that explicit training had a positive effect. The most beneficial effect occurred when the training was given before exposure to the exemplars and the least beneficial when the training was given after an initial implicit acqusition period.

The results of these studies show that the effect of explicit awareness is highly dependent: on the penetrability of the regularity and rules of the underlying structure through its surface manifestation; the nature of the explicit knowledge the subject possesses; and the timing of the explicit knowledge in relation to the task and other processing.

All of the above mentioned studies were carried out with adult subjects. An interesting parallel with implicit learning research can be found in some of the developmental studies carried out with children's voluntary and involuntary memory. There is a growing body of work on voluntary and involuntary memory or incidental memory of type I and type II (according to Postman's (1964) nomenclature). It is not the aim of this dissertation to discuss the topic and its ramifications in detail (see Brown, 1975, 1979; Istomina, 1975; Smirnov, 1973 or Smirnov & Zinchenko, 1969, for a more comprehensive view), but one result of this research is of special interest. Young children perform better on a variety of tasks if they are not under instructions to perform deliberately (e.g.,Istomina, 1975 or Murphy & Brown, 1975). The interpretation given to the superior performance of young children in the involuntary condition, which may be considered implicit, is very similar to the interpretation given by Reber for the effect of explicit awareness. In the involuntary memory research it is postulated that children do not possess the effective strategies necessary for deliberate memory; as a result, forcing them into a deliberate mode interferes with their spontaneous involuntary (implicit) processing.

Similarly, Reber (1976) states:

> They (explicit instructions) interfere with performance, not because they mislead the subjects, but because they put them in an operating set where they mislead themselves. ... It is trivially true, then, that searching for rules will not work unless you can find them. The explicit rule search can jeopardize its user in another more significant way. In addition to producing poor performance because of failure to find well-formed rules, engaging in explicit rule search acts to mask implicit learning processes. (p. 93)

C.2. Analogical versus abstract processes

A second issue that emerges from the research data on implicit processes is the question of the nature of these processes. Brooks (1978) claimed that in order to explain the results of the implicit learning experiments, it was sufficient to postulate the existence of analogical processes and it was unnecessary to conjure up abstraction processes.

Reber & Allen (1978) set out to test this assertion by manipulating the acquisition procedure. In one condition their subjects were required to learn a set of exemplars (derived from an underlying grammar) by a paired association learning procedure (PA). In another condition, the same subjects were required to learn exemplars by observing them (OBS). Reber & Allen found that when their subjects used a PA procedure they had a better memory for the actual stimuli as compared with the condition when these subjects only observed the stimuli. But in the OBS condition the subjects scored higher on their grammaticality judgments than in the PA condition. As Reber & Allen (1978) state:

> Thus with both conditions producing significant learning rates, the OBS procedure is clearly more efficient at imparting exploitable information about the structural status of letter strings. (p. 206)

Reber & Allen (1978) drew two general conclusions from this study: (1) There are at least two discernible types of implicit acquisition processes. The first process is Brooks's "analogical" process which can be characterized by "extensive and relatively accurate memory for individual items." In making grammaticality judgments using such instantiated memory the subjects compare and draw analogies between their specific memories and the items at hand. The second process is an abstraction process. It can be characterized by a rather passive apprehension mode which abstracts the underlying structure from the instances so that it leads to a "relatively high accuracy in assessing grammaticalness of letter strings." Grammaticality judgments are made by assessing individual items for their conformity with the tacit rule system. (2) The type of procedures that the subject will deploy depends on "the type of material to be learned, the way in which it is presented, one's expectations about the task, and one's previous success with these procedures." (p. 219)

These conclusions are compelling but problematic. Neither Brooks (1978) nor Reber & Allen (1978) give an in depth analysis of how these two processes actually operate. A closer look at both processes leads to two questions: (1) What is the nature of the information that is retained regarding the specific exemplars? (2) How does a subject decide whether or not additional exemplars are derived from the same grammar?

C.2.1. Information retained, prototypical theories

The first question was taken up by Reitman & Bower (1973). According to Reitman & Bower there are two radical positions possible: At the one extreme is the view that the subject remembers everything, i.e., the subject compiles a compendium of exemplars of a system or concept. This is the position inferred from Brooks (1978) and incorporated by several induction programs developed in artificial intelligence research on pattern recognition (see Reitman & Bower, 1973). At the other extreme is the proposition that the subject pulls out from the material some abstract representation of it and does not retain any specific memory of the exemplars. Prototypical theories are an example of such a position (e.g., Bransford & Franks, 1971; Franks & Bransford, 1971; Rosch, 1978). Reitman & Bower (1973) conclude that: "The truth doubtless lies between these extremes: Along with the general principle, subjects probably retain some but not all of the exemplar information." (p. 195).

Bearing in mind Reitman & Bower's conclusion, the evidence seems to favor a more abstract memory position rather than a strict specific memory position. There is an impressive body of evidence from research with adults on the extraction of prototypes which supports the abstract thesis claim (Bransford et al, 1972; Cofer, 1973; Jenkins, 1977; Jewson, 1976; Peterson et al, 1973; Posner & Keele, 1968, 1970; Reitman & Bower, 1973; Rosch, 1977; Rosch & Lloyd, 1978). Moreover research done within a constructivistic theoretical framework provides empirical evidence that children, like adults, derive 'holistic' memory representations (e.g., Larsen & Glick, unpublished man,; Paris & Lindauer, 1977; Syradal & Glick, 1970). Finally there is the classic pragmatic argument for the abstract representation position. This argument is based on the notion that the specific memory position is unwieldy, putting a tremendous load on memory and its organization, while remembering a prototypical representation which summarizes many exemplars is much more efficient and makes fewer demands on memory.

C.2.2. Decision making - similarity judgments

The second question, however, is even more problematic. How does a subject decide whether or not additional exemplars are derived from the same grammar or concept? This is the crux of Brooks's (1978) position. His answer to the question is that the subject applies analogical processes, i.e., the subject looks for analogies between the remembered exemplars and the new exemplars. How is this done? How does the subject make a judgment of similarity? There are a number of models of how similarity judgments are carried out (see Tversky & Gati, 1978). What these models have in common is that before the subject can make any comparison he must extract, abstract (or induce) some relevant and irrelevant features (attributes, dimensions) from the stimulus material. Brooks (1978) seems to claim that there are two types of comparisons: one involving complex, precise, rule abstraction; and the other involving more simple, fuzzy and intuitive rules of thumb. As Brooks (1978) states:

> Much of our knowledge is a looser confederation of special cases in which our knowledge of the general is often overridden by our knowledge of the particular. ... Control by a general rule is at least occasionally overridden by information particular of instances, and people accept the rules they express as rules of thumb that do need local correction." (p. 207, 208)

The question is, is it really necessary to postulate two abstraction (comparison) processes? Maybe the difference between these two processes can be explained as a result of a single process activated at different levels of knowledge or at different stages in the acquisition processes. If we accept the latter position, then the results of Reber & Allen's (1978) research can be viewed in another light, namely that there is a complimentary relationship between the subject's ability to acquire a precise memory of the exemplars and his ability to abstract the underlying structure from the exemplars. If the subject is occupied in learning an exact copy of a specific instance he will be less inclined to abstract the underlying rules at that time. Such a subject will abstract the underlying rules only partially. When the subject is required to make a grammaticality judgment, he will abstract the underlying structure from the specific memory that he has acquired. The difference between the PA and the OBS conditions reflects a difference in the extent to which the subject had acquired specific memory of the exemplars during the acquisition phase and the degree to which he had abstracted the underlying structure from the exemplars during the acquisition phase as well as from the remembered exemplars. In other words, there is no difference in the abstraction process, per se, only in when and what it abstracts from.

This interpretation seems to agree with the results of an interesting follow up study carried out by Allen & Reber in 1980. In this study the same subjects that participated in their 1978 study (Reber & Allen, 1978) were asked for grammaticality judgments without any relearning. The results show that subjects could still, two years later, significantly distinguish between grammatical and nongrammatical instances (though, as can be expected, the actual level did decrease). But the difference between the two acquisition conditions (OBS and PA) on the grammaticality judgments seemed to disappear. Only a close introspective analysis reflected some differences between the two modes of aquisition.

In everyday learning situations there is repeated exposure to the material and both types of learning take place. Clearly people pick up specific knowledge as well as abstract underlying knowledge. Only in the laboratory is it possible to manipulate the situation in such a way that the unique properties of acquiring specific knowledge can be contrasted with the abstraction of the underlying structure: when subjects are presented with items that do not have any underlying rule system their only recourse is to learn the specific information. The 'pure' analogous processing produced in the experimental condition can then be contrasted with conditions in which there is an underlying rule system to abstract. The present study was designed to deal with this issue in this manner.

C.3. Contextual effects

The third issue that arises within the implicit learning research which the present research is designed to address is the effect of varying the materials used in the tasks. There is growing awareness in recent research that surface variations in materials induce a change in cognitive processes producing differences in performance in adults as well as children.

Bruner, Goodnow & Austin (1956), in their now classical research on concept attainment found that if they tried to introduce some realism in their studies, not by changing the task but by using thematic material (simple line drawings), their subjects had a harder time attaining a conjunctive concept such as smiling man than they had with a concept such as red circle. The introduction of the thematic material seemed to call forth in the subjects their 'world-knowledge' which influenced their selection of strategies, and made it difficult for them to use simple hypothesis testing strategies that they had used for attaining concepts in the earlier experiments (see also Johnson-Laird & Wason, 1977).

The effect of particular surface manifestations of materials becomes especially dramatic in cross-cultural and developmental research and there has been, in recent years, a great deal of discussion of its implication for hypothesized cognitive abilities and underlying cognitive processes (see Cole & Means, 1981 for an excellent discussion of many of the problems). This issue seems to be especially crucial in implicit processing since by definition these processes are not under the control of conscious analytical processes and knowledge. These processes are strongly determined by the interface between the environmental stimuli and the particular organism acting upon the material.

One approach which is closely related to this issue is the level of processing framework proposed originally by Craik & Lockhart in 1972. The basic notion of the level of processing framework is that specific stimulus materials 'afford' (in the sense proposed by Gibson, 1977) different degrees of interaction with the organism. The degree of involvement or depth of processing by the subject determines the durability of the memory for the stimuli. Taking this research at face value, it is assumed that the more meaningful the stimulus material the better it will be remembered due to the greater depth of processing possible (afforded) with the meaningful material.

Two studies using the same artificial grammar learning paradigm introduced by Reber in his laboratory show an opposite effect of meaningfulness of the stimuli material. The first is an unpublished report by Cantor (man.). In this study, Cantor changed the symbols without changing the underlying grammar. Instead of using letters to produce the patterns of items Cantor used numbers. He found that in this situation implicit learning of the underlying structure was much more difficult. Fifty percent of the subjects did not perform significantly above chance. In addition, there was a negative transfer of learning from letter strings to number strings, as opposed to the positive transfer of learning that Reber (1969) found for one set of letters to another set of letters.

The second study by Howard & Ballas (1980) compared two experimental situations. In both situations the subjects were exposed to patterns of sounds generated from the same finite-state grammar. In the first experiment subjects heard meaningless but grammatically structured patterns of brief duration of pure tones, and in the second experiment, the sound patterns consisted of common real-world sounds (such as clapping, steam hissing). In both of the experiments, the subjects' judgments were compared with the judgments of subjects who were exposed to random patterns (no underlying grammar). Howard & Ballas found that overall performance (hit rate) reached by the grammatical group in experiment 2 (with meaningful sounds) was consistently lower than the performance level reached by the corresponding grammatical group in experiment 1 (meaningless, pure tone sounds). There was no difference in performance between the subjects in both experimental groups who were exposed to nongrammatical patterns. In other words, the meaningfulness of sounds did mot make any difference in performance if the patterns were generated randomly (with no underlying structure), but the meaningfulness was detrimental to performance on the grammatical judgment task when the patterns were grammatical.

The reconciliation of the differences between these results and those expected according to the depth of processing approach lies in the relationship between the meaningfulness of the stimulus material to the subject and the relation this meaningfulness has to the task. If the task is to pick up the underlying structure of the patterned instances, then meaningfulness of the material that is unrelated to the underlying structure will only interfere with the processing and lead to the same difficulty in performance that the Bruner, et al (1956) subjects had with concept attainment from thematic materials. Only if the meaningfulness of the material is directly related to the task will it be beneficial for learning and memory.

Indeed, the results of Howard & Ballas (1980) third experiment are in line with this interpretation. In this study, the experimenter tried to create patterns which were both semantically (real-world sounds) and syntactically sensible, by giving their subjects semantic instructions which suggested that the sounds followed some kind of pattern consistent with real-world events. Thus the <u>semantic</u> <u>instructions</u> made the patterns <u>syntactically</u> sensible. The four possible conditons were compared (grammatical and nongrammatical, with and without semantic instructions). They found that the semantic instructions were beneficial to the grammatical group but were detrimental to the nongrammatical group while the other two groups' performancee fell between these two extremes.

In general, when trying to predict the effects of the stimulus material on cognitive processing one must be careful to specify not only the 'meaningfulness' of the material to the subjects but also the relation of this meaningfulness to the task the subjects are trying to perform.

GENERAL EXPERIMENTAL METHODOLOGY

The present study consists of two experiments. The experimental methodolgy used in both experiments was very similar to the implicit learning paradigm introduced by Reber (1967). A number of modifications were made to accommodate the age of the subjects.

SUBJECTS

Experiment 1 was undertaken to demonstrate that children posses implicit processes for abstracting complex information. In other words, children's performance in tasks congenial to acquisition of an underlying grammar resembles the performance of adults in the same tasks. There is no previous research with children employing the particular artificial grammar learning paradigm used in this research. As a result, the decision as to what age groups to select was guided by two considerations: to select children from the youngest possible age group without getting floor effects (while preserving the complexity of the grammar and tasks so that the adults would not find the task trivial); and to add another children's group of a slightly higher cognitive level for comparison in case age related effects were found. Hence, there were three age groups in Experiment 1: an adult group and two children's groups (5-7 years old and 9-10 years old).

Experiment 2 was designed to learn more from a developmental perspective, about the issues raised by the current body of implicit learning research, and more specifically the effect that various manipulations related to these issues may have on the implicit processing of children of different cognitive levels. Therefore the subjects for the second experiment were children from three age groups each representing, according to traditional developmental research, a different stage of cognitive development.

STIMULI

The stimulus material used in the implicit learning research was modified in order to accommodate the age of the subjects. Instead of using letters to produce strings of symbols according to a finite-state grammar, simple colored geometric shapes were used (see Figure 2 and Figure 3). In addition, there were only four (instead of five) different symbols used to produce sequences of a maximum length of seven (rather than eight) symbols. In all other respects the materials were constructed in the same manner as the materials used in the ILT research.

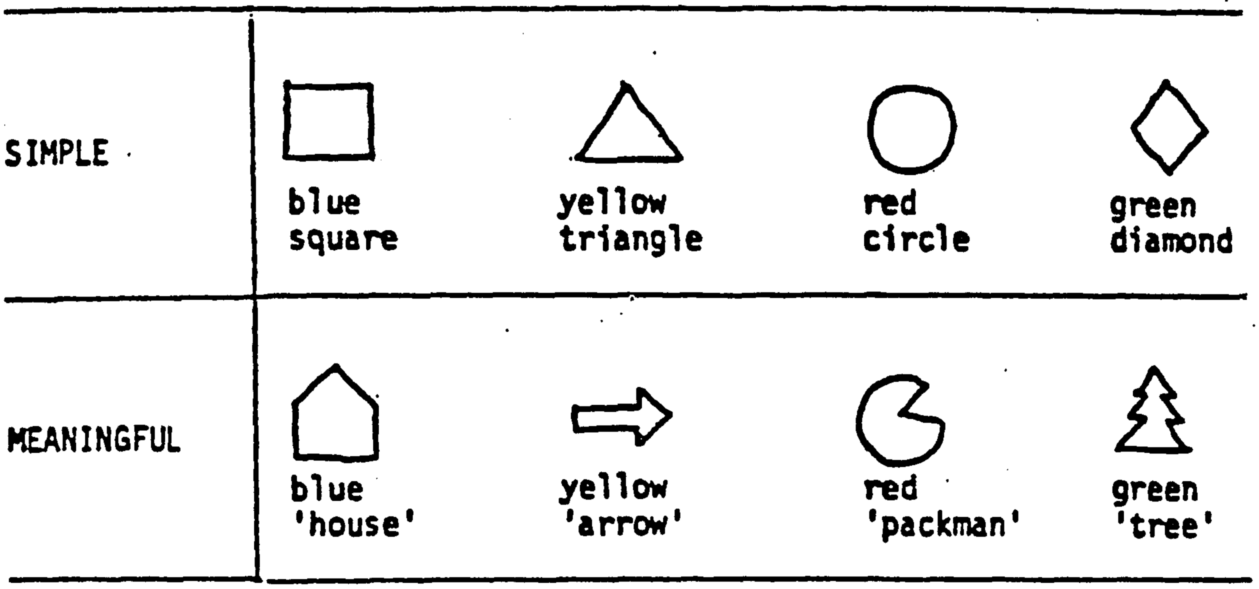
PROCEDURE

The procedure in both experiments was the same. The experiment, like the implicit learning studies was divided into two parts: an acquisition phase and a testing phase.

Part I - The Acquisition Phase - In part I the subjects were required to learn a set of sequences generated from a finite-state grammar. A number

Figure 3

The 'simple' and 'meaningful' stimuli



of learning techniques have been used by Reber and his associates: reproduction of sets of sequences (Reber, 1967, 1969, 1976) or reproduction of one sequence at a time (Reber & Lewis, 1977); observation (Cantor, man.; Lewis, 1975; Reber & Allen, 1978; Reber et al, 1980; Reber & Kassin, 1977) and paired associate learning (Brooks, 1978 and Reber & Allen, 1978). There have been a number of problems with the observational technique (see Lewis, 1975 p. 54, for example) which would only be aggravated by the young age of some of the subjects. Therefore, the learning task chosen was a reproduction of the items one at a time. In order to minimize production difficulties that the youngest children may have the subjects were given a set of prepared cards for the reproduction task. On each card was depicted a single symbol (colored shape) and the subjects' task was to use these cards in order to reproduce correctly, from memory, each string of symbols.

In Reber's studies the stimuli were presented for a predetermined time period, regardless of the length of the sequence. In the present study, which includes such a wide range of age groups, a predetermination of the time allotted for studying the sequences might be problematic since the subjects could be expected to vary to a great extent in the optimum time they require for learning the sequences. Therefore, the subjects were allowed to determine for themselves the amount of time they wished to spend in studying each item rather than the experimenter setting an a priori pace for all the subjects. In Experiment 2, the total time each subject needed to complete the task was added as an additional dependent measure.

Part II -The Testing Phase The greatest deviation from Reber's methodology was in the testing phase. Subjects were required to perform a recognition task rather than a grammaticality judgment.

In Reber's research grammaticality judgments were used to detect the abstraction of the underlying structure by the subjects. A grammaticality judgment, however, is a very difficult concept to explain to young children, the subjects of the present study; therefore, a different method had to be found. Research done within a prototypical and constructivistic approach has shown that subjects make many mistakes in recognizing and distinguishing between old and new information if both represent the same prototype or concept. It was, therefore, assumed that a recognition task would be applicable for our purpose. Specifically, subjects presented with new grammatical instances should find it difficult (as reflected in the number of errors) to differentiate them from the instances previously seen. In addition, the abstraction of the grammar should make it easier for the subjects to distinguish between old grammatical instances and nongrammatical instances. In fact, if this is the case, the greater the number of violations of the grammar in an instance the easier it should be for the subjects to state that the nongrammatical instances are unfamiliar.

In part II the subjects were presented with three types of sequences and required to decide whether or not they had seen (in the reproduction task) each of the sequences. The three types of sequences presented for recognition in part II were: (1)old grammatical sequences,

sequences that were presented in the acquisition phase; (2) new grammatical sequences, strings generated from the same finite-state grammar as the reproduction sequences that were not shown in part I; and (3) nongrammatical sequences, strings that were generated by violating the grammar either once or twice.

EXPERIMENT 1

METHOD

A. Subjects

Thirty-one subjects participated in the first experiment. There were three age groups: (1) 5-7 year olds; (2) 9-10 year olds; (3) adults. All the children (Group 1 and Group 2) were taken from the Newton, Mass. public school system. In Group 1 there were initially eleven children. One kindergartner did not have the patience to complete the task and was dropped. Thus there were 10 children - 8 males and 2 females - were used (7 first graders and 3 kindergartners); their mean age was 6 years and 5 months (6;5), range: 5;5 - 7;2. In Group 2 there were 10 children - 4 males and 6 females (9 fourth graders and 1 fifth grader); their mean age was 9;10, range: 9;0 - 10;8.

The adults (Group 3) were all volunteers from various professions (college students, teachers, businessmen/women, artists). This group was divided into two subgroups: adults and senior adults. The adult group consisted of 7 subjects - 2 males and 5 females, mean age 26, range 19 - 36. The senior adult group consisted of 3 subjects - 1 male and 2 females, mean age 62, range 61 - 64. The senior adult group was not included in the statistical analysis (due to the small number of subjects) and the results of this group is reported in Appendix A. All statistical analysis reported includes 27 subjects, unless otherwise stated.

B. Design

The only variable that was manipulated in Experiment 1 was the age of the subjects.

C. Procedure

All the subjects were tested individually. At the beginning of the study they were told that they would participate in a number of memory games. The experimenter and the subject were seated side by side next to a table on which the materials for each task were placed. The experiment was divided into two parts. The subject was given instructions before each part. After completing Part I and Part II the entire experiment was run again with the same materials. The subject was not informed that the experiment was being repeated. Most of the subjects (asked after the experiment) believed that they had seen a different sets of materials the second time. The aim of the repetition of entire procedure was to find out if an awareness that recognition of the sequences might be required will affect the nature of the recognition the second time.

C.1. Part I - Reproduction - the acquistion phase

The experimenter placed on the table in front of the subject a box divided into four cells. In each cell there were ten identical cards. On each 6x8 cm. card one of the four colored shapes used in generating the sequences was reproduced. Thus there were 40 cards, ten for each shape. The subject was informed that he would be shown, one at a time, strings of shapes of various lengths and that he would be required to reproduce these strings from memory with the prepared cards in the box in front of him. The sequences were depicted on 7x28 cm. posterboard. The experimenter placed each sequence in front of the subject and allowed the subject to study each pattern until he indicated that he was ready. The sequence was then taken away and the subject attempted to reproduce the pattern with the prepared cards. If the subject reproduced the sequences correctly, he was shown a new sequence. If he did not reproduce the sequence correctly, the same pattern was shown again. The subject had four attempts to produce the correct pattern. After each attempt the cards were returned to the box and the subject was not given any feedback except for being told whether he would be shown the same pattern or a new pattern. There were 15 sequences in Part I (see Table 1 for details of the lengths of sequences and Figure 2 for the actual sequences shown). The sequences were presented in random order, except for the first sequence in the first reproduction which was always the shortest pattern (with three shapes).

C.2. Part II - Recognition - the testing phase

The experimenter took out another set of sequences and put it on the table, face down. The subject was informed that these were additional sequences and that in this set were some sequences that the subject had just seen and some that were new. The experimenter turned over the patterns one at a time and asked the subject if he had seen (reproduced) that sequence. In addition, for each of the patterns, the subject was asked how confident he was of his decision (that 'yes' he

Table 1

Sequences length: total possible G sequences and distribution of G and NG sequences in Part I and Part II

Experiment 1

Length of seq.	possible G seq.	G sequen. Part I A	G seq. Part I&II (OLDG) B	G seq. Part II (NEWG) C	NG seq. Part II (NONG) D	Total seq. Part I A+B	Total seq. Part II A+B+C
3	2	0	1	1	2	1	4
4	3	1	1	1	2	2	4
5	4	1	1	1	2	2	4
6	7	2	2	2	4	4	8
7	11	3	3	2	5	6	10
Total	27	7	8	7	15	15	30

G= Grammatical sequence NG= Nongrammatical sequence had or 'no' he had not seen the pattern before). Confidence was introduced with the help of 'smiley', 'neutral' and 'sad' faces (Figure 4) which were each drawn on a 5x8 cm. card placed on the table in front of the subject. There were three degrees of confidence: (1) smiley - very sure; (2) neutral - a little sure, a little confused; and (3) sad - very confused.

The subjects were presented with 30 sequences, in random order, generated in the following manner (see Table 1 and Figure 2):

8 'old grammatical' (<u>OLDG</u>) instances shown in Part I, generated from the finite-state grammar in Figure 1.

7 'new grammatical' (<u>NEWG</u>) instances not shown in Part I, generated from the same grammar as the OLDG instances.

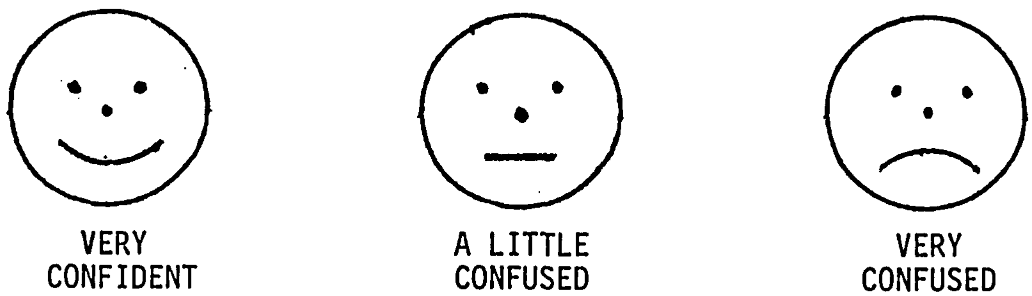
15 'non grammatical' (<u>NONG</u>) instances generated by violating the grammar:

- 7 (<u>NONG1</u>) which violate the grammar once either in the beginning, middle or end of the pattern;
- 8 (<u>NONG2</u>) which violate the grammar twice in two positions either in the beginning and/or middle and/or end of the pattern.

The full set was run through once with no time constraints. Then there was a short break (about five minutes) and the entire procedure beginnning with the acquisition phase was run through again with the same stimulus material.

Figure 4

Response Confidence Scale



PREDICTIONS

The aim of the first experiment was to test whether recognition tasks could be used to detect the activation of implicit processing of an abstract grammar and whether the artificial grammar learning experimental paradigm could be extended to young populations.

In Experiment 1 evidence for the activation of implicit processing of the underlying structure was determined by comparing the subjects' scores (number of correct rejections) for the NEWG and NONG. If there was no significant difference between the NEWG and NONG scores than there would be no evidence for abstraction of the grammar. Conversely, if NONG scores were higher than the NEWG scores, and the NONG2 scores were higher than the NONG1 scores then the implicit processing of the underlying grammar would be demonstrated.

The first prediction of Experiment 1 was that the subjects recognition scores (percent of correct "no") would be highest for NONG2 and lowest for NEWG, with NONG1 in between. Such a result would be taken as evidence for the existence of implicit processing.

The second prediction of Experiment 1 was that both children's and adults' recognition scores would exhibit the effect of implicit processing, i.e., for all age groups the scores would be NONG2>NONG1>NEWG, although the actual scores for the different age groups might differ.

RESULTS

A. Part 1 - Acquisition

For each subject the total number of trials needed to reproduce correctly the 15 sequence was computed. A one way ANOVA for the effect of age was run for the 27 subjects for the total number of trials. There was a highly significant effect of age [$F(2,24)=11.15$, $p<0.001$]. The total number of trials required to produce the fifteen sequences correctly decreased significantly with age. The difference between the youngest age group and the other two age groups was significant [$F(1,24)=12.56$, $p<0.002$]. There was no significant difference in the total number of trials between the adults and the older (9-10 year old) children [$F(1,24)=1.37$, $p=.25$].

Since Part I was run twice it was possible to learn more about the effect of repeating the task by comparing the two acquisition scores for each subject. The learning that takes place over repetition of the acquisition task is reflected in the change in the total number of trials required to reproduce the fifteen sequences correctly the second time as compared to the first time. A split plot with one between factor and one within factor ANOVA was run for the 27 subjects. There was a highly significant age effect [$F(2,24)=9.87$, $p<0.001$] and a significant effect of repetition [$F(1,24)=4.43$, $p=0.04$]. There was no age x repetition interaction. The mean number of trials decreased with age and with repetition of the task (see Table 2).

Table 2

Mean Number of total trials to reproduce 15 sequences correctly - by age and repetition

Experiment 1

N=27

Group	Repetition 1st time	2nd time	1st&2nd
5 - 7	29.00	26.20	27.60
9 - 10	22.30	21.30	21.80
Adults	19.87	18.71	19.29
Mean	24.15	22.44	23.30

B. Part II - testing

B.1. Correct Recognition

The subject's answer was correct if he said 'yes' to an OLDG sequence and 'no' to a NEWG, NONG1 and NONG2 sequence. For each subject the total number of correct answers to each type of sequence divided by the total number of sequences of that type was computed to give the subject's percent correct score for each type of sequence. Thus for each subject there were four recognition scores: OLDG, NEWG, NONG1, and NONG2. Means in Table 3.

A split plot with one between factor (age) and one within factor (type of sequence) ANOVA was run for the 27 subjects (see Appendix C, Table 18). There was no basis to assume that the within subject factor (type of sequence) fulfills the assumption of equal correlation between the scores (i.e., assumption of compound symmetry). In order to avoid any excessive number of significant Fs, a correction procedure was applied by using a multivariate test rather than a univariate test of this factor in the ANOVA, with the GANOVA microcomputer program developed by Brecht & Woodward (1984).

There was no significant age effect [$F(2,24)=.38$, $p=.69$]. There was a highly significant type of sequence effect for both multivariate tests (Wilkes Lambada and Pillai-Bartlett Trace - $p<0.0001$). In addition there was no significant age x type of sequence interaction ($p=.29$).

Table 3

Mean percent correct recognition

by age and type of sequence

Experiment 1

N=27

Type of sequence	Age Group 5 - 7	9 - 10	Adults
OLDG	67.70	67.70	77.00
NEWG	57.20	51.60	37.00
NONG1	71.57	73.00	69.29
NONG2	86.40	87.00	83.57
Mean	70.70	70.03	66.77

Paired comparisons between the three types of sequences show that:

(1) OLDG scores are significantly higher than the NEWG scores [$F(1,24)=16.85$, $p<0.001$];

(2) NONG2 scores are significantly higher than the NONG1 scores [$F(1,24)=11.62$, $p<0.01$];

(3) NONG1 scores are significantly higher than the NEWG scores [$F(1,24)=28.02$, $p<0.001$];

In other words the relationship between the three types of sequences that were new (i.e. not presented in Part I) was NEWG $<$ NONG1 $<$ NONG2. This relationship exists within each age group as well as between age groups (see Table 3 and Appendix C, Table 19).

In order to check whether subjects had a preference for either saying 'yes' or 'no', a comparison was carried out between the scores for the OLDG (for which the correct answer was a 'yes') and the NEWG, NONG1 and NONG2 (for which the correct answer was a 'no'). There was no significant difference between the 'yes' and 'no' scores [$F(1,24)=.25$, $p=.63$].

It is important to note that all subjects performed significantly above chance (a total score above 60% - more than 18 out of 30 sequences identified correctly) except one six year old who got 53% correct. The total correct scores for each age group was at least 20 (5-7 = 21.3, 9-10 = 21, and Adults = 20.14).

B.2. Effect of repetition

A split plot with one between factor (age) and two within factors (repetition and type of sequence) ANOVA was run for the 27 subjects to find out if repeating the recognition and reconstruction task had any effect on the recognition score for the different types of sequences. There was no significant effect of repetition nor any significant interaction of the other two factors with repetition.

B.3. Confidence scores

For each sequence the subject was asked for a confidence rating. A split plot with one between factor (age) and one within factor (type of sequence) ANOVA was run for the confidence scores. There were no significant effects for age and type of sequence, nor any interaction between the two factors. Confidence was greater for all age groups on the NONG and OLDG sequences as compared to the NEWG sequence, although the difference was not significant. In general, the adults were less confident than the children, but again, the difference was not significant.

B.4. Place of violation

The NONG sequences were generated by violating rules of the grammar. The violations could occur in any position in the generated sequence. In the first experiment, for the 15 sequences, the total number of violations in the beginning, middle and end were the same. Therefore, it was possible to test if there was any significant effect of the place of violation on the subjects' recognition of the nongrammatical instances.

A split plot with one between factor (age) and one within factor (place of violation) ANOVA was run. Place of violation was the only factor that was significant age [$F(2,23)=4.18$, $p=.028$)]. Although there was no significant age x place interaction, a closer look at the results shows that these effects are due to: (1) there was no place effect for the youngest group; (2) the older children and adults were more sensitive to violations in the middle or end of the sequences than the beginning of a sequence. In other words, if the violation was in the beginning of a sequence the older subjects were more likely to state incorrectly that they had seen that sequence than if the violation was in any other position.

CONCLUSIONS

The results of the first experiment were in line with the predictions made for this experiment. A number of conclusions may be tentatively drawn on the basis of these results:

(1) First and foremost, this experiment demonstrates that recognition tasks can be effectively utilized in experimental situations to test the activation of implicit processes. The recognition scores exhibit definite evidence of some degree of abstraction of the underlying grammar by the subjects. The compatability of recognition tasks makes it possible to extend the experimental paradigm employed by Reber and his associates with adults to younger populations.

(2) As predicted, both children and adults abstract complex underlying structure. For all age groups the abstraction of the

underlying grammar was demonstrated by the significant relation: NEWG<NONG1<NONG2 and NEWG<OLDG. In other words, the existence of some abstract knowledge of the grammar makes it more difficult for the subjects to classify new grammatical items correctly as compared to the other types of sequences.

(3) There were, as predicted, no significant age differences in the subjects' implicit processing. This result is especially interesting given the widespread age range of the subjects (from five year olds to 36 year old). It seems that at least as young as five years of age children have available implicit processes that can abstract complex underlying structures. Moreover, the activation of the implicit processes is manifested in the childrens' performance even though they could not, most probably, articulate the rules of the grammar, just as Reber's adult subjects could not explicate their criteria for their grammaticality judgments.

(4) There were no significant differences in the confidence levels of the subjects for the different type of sequences and for the different age groups, although the trends were in the expected direction (decrease in confidence for the NEWG as a result of the abstraction of the underlying grammar). This result may be due to the small size of the sample. The second experiment with the larger sample will be a better test of the utility of using confidence ratings in implicit processing research.

(5) Subjects were not indifferent to the place of violation of the grammar. This result may be in some way indicative of the nature of implicit processing. It is premature to try and draw any conclusion from this isolated result.

EXPERIMENT 2

METHOD

A. Design

In the second and main experiment of this dissertation there were four experimental conditions. The first condition (ImS) served as a control condition. In the other three conditions, one of the variables in the ImS condition was varied. Three variables were manipulated in this manner. (1) Instructions: there were two types of instructions: neutral implicit (Im) and explicit (Ex). The implicit instructions were given before each task. They explained how to perform the task. The explicit instructions were the same as the implicit instructions with an addition in Part I. The additional instructions informed the subject that the sequences were part of a game and that discovering the rules of the game could facilitate the reconstruction. (2) Stimuli: two types of stimuli were used for creating the sequences: simple (S) and meaningful (M) (see Figure 3, p. 35). The 'simple' stimuli were simple colored geometric shapes (circle, square, triangle and diamond). The 'meaningful' stimuli were also simple colored shapes but with some real-world significance (tree, house, arrow and pie or packman). The sequences created with both types of stimuli were generated from the same underlying grammar (see Figure 1, p. 8). (3) underlying structure - there were two types of underlying structure: grammatical (G) and random (R). The grammatical (G) structure was the same finite-state grammar used in experiment 1 (see Figure 1, p. 8 for a schematic representation of the grammar and Figure 2 for all the possible S type sequences of the length of three to seven shapes). The random (R) series was, as the name indicates, without an underlying structure. Sequences in the R series were generated by repeatedly, randomly picking a shape from the stimuli set to produce sequences of any desired length.

Thus the four conditions of experiment 2 were:

ImS - the control condition with implicit instructions, simple stimuli and grammatical underlying structure.

ImM - same as control condition but instead of the 'simple' stimuli the 'meaningful' stimuli were used.

ExS - same as control condition but instead of implicit instructions the subjects received explicit instructions.

R - same as the control condition but instead of the existence of an underlying grammar the sequences were generated randomly, i.e., there was no underlying structure.

The findings of sex differences in spatial ability is the most presistent of the individual differences on a variety of multifactor tests. In many situations it seems that males, as a group, exhibit significantly better spatial skill than females (see Harris, 1978, for example, for an overview). Moreover, sex differences have been found in tasks similar to the tasks in this experiment. Therefore, great care was taken in the design so that for every manipulation the existence of sex differences would be detected.

There were three age groups in Experiment 2: (1) 5 - 7 year old; (2) 9 - 11 year old; and (3) 12 -14 year old. Age and sex were balanced for each of the four conditions.

To summarize: the design of Experiment 2 called for 24 cells — 4(condition)x3(age)x2(sex). See Table 4 for complete details.

B. Subjects

One hundred and twenty-one children (fifty-eight males and sixty-four females) from the Newton, Mass. and Rye Neck, N. Y. public school system participated in this study. Except for the youngest age group (for which the parents volunteered for the child) the children all volunteered their time to help in a study about memory (after getting their parents' permission). Four boys were dropped from the study. Two, a kindergartner and a fourth grader, were dropped because they had a great deal of difficulty in carrying out the tasks (their teachers later confirmed that they had a learning disability). The other two children did not want to continue with the tasks (each child was informed that he could stop if he didn't feel like continuing with the tasks). Two girls were tested with the wrong recognition stimuli so their recognition scores were not included in the analyses but their scores in the reconstruction task (Part I) were included in the analyses.

The subjects were recruited from three age groups. In each age group the subjects were randomly assigned to one of the four conditions.

Table 4

Design of Experiment 2

ImS	ImM	ExS	R	N
1gSImG	1gMImG	1gSExG	1gSImR	20
1bSImG	1bSImG	1bSExG	1bSImR	20
2gSImG	2gSImG	2gSExG	2gSImR	21*
2bSImG	2bSImG	2bSExG	2bSImR	17
3gSImG	3gSImG	3gSExG	3gSImR	20
3bSImG	3bSImG	3bSExG	3bSImR	17
30	28	27	30*	115*

* In Part I there are 2 more subjects

Key

Each cell first letter - age group, second letter - sex, third letter - type of stimuli, fourth and fifth letters - instructions, and sixth letter - structure:

1 - 5-7 year olds	b - male	S - simple	Im - Implicit
2 - 9-11 year olds	g - female	M - meaningful	Ex - Explicit
3 - 12-14 year olds			

G - Grammatical
R - Random

The subjects' distribution was as following:

(1) 5 - 7 year old - Forty children (20 boys and 20 girls). Mean age was 6;8, range was 5;10 - 7;5. (16 were kindergardners and 24 were first graders). In each condition there were five boys and five girls.

(2) 9 - 11 year old - Thirty eight children (40 in Part I) (17 boys and 21 girls). Mean age 9;9, range 8;5 - 11;4. In all the conditions there were five boys and five girls except for the ExS condition in which there were six girls and two boys*. (In the random condition in Part I there were two extra girls).

(3) 12 - 14 year old - Thirty seven children (17 boys and 20 girls). Mean age 13;10, range 12;1 - 15;10. Five boys and five girls in every condition except in the ExS condition in which there were four boys and five girls and in the ImM condition in which there were three boys and five girls*.

All together there were 117 children in the statistical analyses of the results of Part I and 115 children in the statistical analyses of Part II.

C. Procedure

The procedure in Experiment 2 was very similar to Experiment 1

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* Although the design called for 5 girls and 5 boys in each condition at each age, pragmatic factors of availability prevented this in a few cases.

except for the following changes:

(1) In Part I - in addition to the response of the subject, the experimenter noted the total time it took the subject to reproduce the fifteen sequences correctly.

(2) The composition of the recognition set of thirty sequences was changed. In the ImS, ImM and ExS condition there were:

10 - OLDG sequences, presented in Part I, generated from grammar;

10 - NEWG sequences, not shown in Part I, generated from grammar;

10 - NONG sequences, violating the grammar once or twice.

In the R condition the sequences were:

10 OLDR - Random sequences presented in Part I;

10 NEWR - New random sequences (not presented in Part I);

10 NONR - sequences generated by changing either once or twice sequences presented in Part I. Five of the NONR sequences were based on sequences that were shown only in Part I, and five were base on sequences that were shown in Part I and as OLDR in Part II.

See Table 5 for details of the lengths of the sequences.

PREDICTIONS

In the second experiment there were four conditions. The first

Table 5

Sequences length: total possible G sequences and distribution of G and NG sequences in Part I and Part II

Experiment 2

Length of seq.	possible G seq.	G sequen. Part I A	G seq. Part I&II (OLDG) B	G seq. Part II (NEWG) C	NG seq. Part II (NONG) D	Total seq. Part I A+B	Total seq. Part II A+B+C
3	2	0	1	1	1	1	3
4	3	1	1	1	1	2	3
5	4	2	1	1	1	3	3
6	7	1	3	3	3	4	9
7	11	1	4	4	4	5	12
Total	27	5	10	10	10	15	30

G= Grammatical sequence NG= Nongrammatical sequence condition (ImS) serves as the control condition and was essentially the same as in Experiment 1. In each of the other three conditions, one variable was manipulated in order to address an issue raised in the implicit learning research (see Introduction, Section C).

In every condition of Experiment 2 there were three age groups: 5-7, 9-11, and 12-14. Thus it was possible to detect any developmental variations in the performance of subjects in each of the conditions and between conditions.

A. The effect of predisposition

The first manipulation compares the ImS condition (in which subjects received implicit instructions) to an explicit predisposition condition (ExS). In the ExS condition subjects received instructions intended to promote in the child an awareness of the rule governed nature of the materials.

In Reber's 1976 research the explicit instructions given to adult subjects was detrimental to their grammaticality judgments (see Section C.1.). In the present study the subjects were children and they had to carry out a recognition judgment rather than a grammaticality judgment. Therefore, it was predicted that: (1) the youngest children would not be affected by the instructions since they lack the experience and the skill necessary to translate the instructions into a coherent strategy of looking for rules; (2) the oldest group would be affected by the explicit instruction. The explicit instructions should be detrimental only when the abstraction of the grammar is reflected in the performance of the subject. In other words, there should be no change in the OLDG scores, there should be an increase in the NEWG scores (due to a decrease in the abstraction of the grammar) and a decrease in the NONG scores (due to the decrease in abstraction).

Another type of explicit awareness was created by repeating the procedure. Having gone through both parts of the experiment the first time subjects were now aware of the nature of the tasks. The first run of the experiment could, in principle, produce two types of effects on the second run: performance and process. The performance effects include facilitating effects resulting from familiarity with a task, as well as impeding effects such as fatigue, boredom, and proactive inhibition. The process effects are any variation in the nature of the processing of the information that is brought about by repeating the reproduction and the recognition task the second time. It may be that the knowledge of the tasks will generate greater attention to the specific exemplars and impede the free flow of the implicit processes or that a second exposure to the material will increase the abstraction of the underlying grammar. Theoretical considerations do not predict what the precise effects might be.

B. 'Analogical' versus 'abstract' processing

The second manipulation compares the ImS condition in which there was an underlying grammar with a random (R) condition. In the R condition the order of the shapes in the sequences was random (i.e.

there was no underlying grammar). The subject could not abstract any underlying grammar. Therefore, the subjects' knowledge should consist of specific memories of the exemplars presented in Part I.

The artificial grammar learning studies (see Lewis, 1975 for overview and Reber, 1967) have repeatedly shown that the existence of an underlying structure facilitates learning. Thus, it was predicted that learning in the ImS condition would be quicker and easier than the learning in the random condition as expressed by the number of trials to learn and the total time of learning. (This facilitation effect is also another type of evidence that the subjects do indeed abstract the underlying structure.)

In the ImS and R conditions the recognition of the old sequences requires specific memory. Hence, there should be no difference between the OLDG and OLDR scores, though different age groups may vary in their memory ability.

In the ImS condition, it is hypothesized that the subjects abstract the underlying grammar. This knowledge affects the subjects' NEWG and NONG scores. On the other hand in the R conditon there was no underlying grammar to abstract, thus the NEWR scores should be higher than the NEWG scores. In addition the NEWR scores should be higher than the NONR (due to the greater similarity of the NONR to the OLDR).

The developmental perspective is especially interesting in the comparison of these two conditions. According to the implicit processes interpretation of the Nelson & Nelson Cognitive Pendulum Theory, it was predicted that the quality of implicit processing will vary at different cognitive levels. The children in the second experiment were chosen from the three age groups that represent, according to most developmental theories, three different cognitive levels. It was predicted that, if indeed there were a difference in the quality of implicit processing at the various cognitive levels, it would be manifested most clearly if we compare each age group's performance in the R condition to the performance of the same age group in the ImS condition.

C. Contextual effects

The third manipulation compares the ImS condition with the ImM condition. The only difference between the two conditons was in the surface manifestation of the sequences. In the ImS condition the sequences consisted of patterns of simple geometric shapes (circles, triangles, squares and diamonds). In the ImM condition, the sequences consisted of simple shapes that should remind the children of objects that have some real-world significance (tree, house, arrow, and pie or pacman). There was, however, no relationship between the real-world meaning of these shapes and the underlying rule structure that generates the sequences.

As in all other parts of the research, the question was approached developmentally. There were two forseeable outcomes of the manipulation: on one hand, the 'meaningfulness' of the materials in the ImM condition may be detrimental to abstraction of the underlying structure by diverting the attention of the subjects to irrelevant aspects of the material; on the other hand, the 'meaningfulness' may increase the children's attention and involvement in the task and may elicit quicker and more profound acquisition.

Therefore, it was predicted that the change of the shapes in the ImM condition would differentially effect the children depending on their age. Meaningfulness of the material would be most beneficial to the youngest age group by increasing their interest in the tasks. While it would be the most detrimental to the oldest children who would be more likely to be misguided by the 'unrelated' meaningfulness of the materials because of their increased knowledge and experience.

RESULTS

In order to present the results more clearly the result section will be divided into two sections: Section A will present a general overview of the statistical analyses of all the quantitative data; and Section B will present a more detailed look at the results in relation to the three issues that experiment 2 was designed to address (see Section C of introduction).

Section C of introduction). The effect of repeating the entire procedure twice will be discussed in the section dealing with the effects of predisposition. Though this division of the results section may introduce some redundancy, it is necessary for a coherent presentation.

A. General overview of results

As explained in the methodology section there were four independent variables in the experiment: (1) condition - there were four conditions: ImS, ImM, ExS, and R; (2) age - there were three age groups: 5-7, 9-11, and 12-14; (3) sex; (4) type of sequence - in Part II there were three types of sequences: OLDG, NEWG, and NONG (in the R condition they were: OLDR, NEWR, and NONR).

The first three variables are between subject variables. The last variable, type of sequence, is a within subject variable. As already explained in the results of Experiment 1, there was no reason to assume that the assumption of compound symmetry is maintained in the scores for the different types of sequences so a correction was applied by using a multivariate test for the 'type of sequence' in all ANOVAs which included this variable. All the statistical analyses, unless otherwise specified, were done with the GANOVA Apple II micro computer program developed by Brecht & Woodward (1984).

A.1. Part I - Acquisition - reproduction task

A.1.1. Total number of trials

A three way ANOVA was run for 117 subjects for the total number of trials reqired to reproduce the fifteen sequences correctly (see Appendix C, Table 20). The only significant factor was age [F(2,93)= 51.99, p<0.0001]. All other factors and interactions were not significant.

With age subjects required fewer trials to reproduce the sequences correctly. The mean total trials for each age group was: Group 1 =31.95, Group 2 =22.28, and Group 3=19.02. There was no significant effect of condition [F(3,93)=1.61, p=.19], though the mean total trials for each condition were in the general direction that was expected. The R condition required the most trials and ImM condition required the least amount of trials (R=26.06, ImS=24.73, ExS=24.09, and ImM=22.79). The only exception to the expectations was the ExS condition which required slightly less trials than the ImS condition. See means in Table 6.

A.1.2. Total time

A three way ANOVA was run for the 117 subjects for the total time it took each subject to complete the reproduction task (Appendix C, Table 21). The factors that were significant were: condition [F(3,93)=5.02, p<0.01] and age [F(2,93)=80.57, p<0.0001], as well as the interaction of condition with age [F(6,93)=2.17, p=0.05].

The condition effect reflects a significant difference between the

Table 6

Mean total trials to reproduce 15 sequences

correctly - by age and condition

Experiment 2

N=117

Age	Condition: ImS	ImM	ExS	R	Mean Age
5 - 7	34.30	28.90	30.70	33.90	31.95
9 - 11	21.30	21.50	21.75	24.59	22.28
12 - 14	18.60	17.97	19.83	24.59	19.02
Mean Condition	24.73	22.79	24.09	26.06	

ImS condition and the other two structured conditions (ImS vs. ImM - F(1,93)=4.60, p=0.03; ImS vs. ExS - F(1,93)=5.34, p=0.02]. There was no significant difference between the ImS condition and the R condition [Ims vs. R - F(1,93)=.78, p=.38], see Table 7 for mean total times.

The age effect is due to a decrease with age in the time needed to reproduce correctly the entire sequence set (Table 7). A paired comparison between the ages shows that the difference between the age groups is significant [5-7 vs. 9-11: F(1,93)=82.66, p<0.0001; 9-11 vs. 12-14: F(1,93)=8.30, p<0.01].

The condition x age interaction reflects a significant effect of condition in the two younger age groups [5-7: F(3,93)=6.9, p<0.001 and 9-11: F(3,93)=2.61, p=0.05]. There was no significant effect of condition for the oldest age group [12-14: F(3,93)=.29, p=0.83].

A.1.3. The relationship between total trials and total time

A. Correlation - The correlation between the total number of trials and the total time was very high and significant (r=0.83, p<0.001).

B. Rate of reproduction - In order to find out more about the source of improvement with age in the reproduction task, the rate of reproduction was computed for each subject. The rate of reproduction is the total number of trials for a subject divided by that subject's total time. A change with age in the rate of reproduction is indicative of whether the improvement with age is merely a function of greater accuracy in the

Table 7

Mean total time to reproduce 15 sequences

correctly - by age and condition

Experiment 2

N=117

Age	Condition ImS	ImM	ExS	R	Mean Age
5 - 7	26.90	19.00	18.90	24.20	22.25
9 - 11	11.40	11.20	10.33	15.79	12.23
12 - 14	8.45	8.60	8.62	10.20	8.97
Mean Condition	15.75	12.93	12.33	16.73	

reproduction or in addition a result of greater speed of executing the task.

A three way ANOVA was done (see Appendix C, Table 22). The factors that were significant were: condition [F(3,93)=4.88, p<0.01] and age [F(2,93)=36.69, p<0.0001]. There were no significant interactions.

The effect of condition is due to significant differences in rate between the ImS conditon and the ExS and R condition. See mean rates in Table 8. [ImS vs. ExS - F(1,93)=3.97, p=0.046; ImS vs. R - F(1,93)=3.63, p=0.057]. There was no significant difference in rate between the ImS condition and the ImM condition [ImS vs, ImM- F(1,93)=0.05, p=0.81].

The age effect is due to an increase in rate with age, i.e., with age subjects worked more quickly (mean rate for the age groups was: Group 1=1.48, Group 2=1.93 and Group 3=2.21 trials per minute). Paired comparisons between age groups were significant [5-7 vs. 9-11: F(1,93)=26.98, p<0.001; 9-11 vs. 12-14: F(1,93)=9.89, p<0.01].

A.1.4. Summary of results Part I

In general for Part I there was a strong effect of age. The older subjects inmproved in each type of measure. There was a significant condition effect only for the time measures. There were no sex differences found in this part of the study.

Table 8

Mean rates for reproducing 15 sequences

correctly* - by age and condition

Experiment 2

N=117

Age	Condition ImS	ImM	ExS	R	Mean Age
5 - 7	1.34	1.52	1.66	1.43	1.48
9 - 11	1.93	2.00	2.17	1.64	1.93
12 - 14	2.33	2.16	2.39	1.98	2.21
Mean Condition	1.87	1.89	2.07	1.68	

* Number of trial per minute.

A.2. Part II - Recognition

A.2.1. Total correct

The total correct recognition scores were computed by adding the correct scores for the OLDG, NEWG and NONG sequences (i.e, 'yes' for the OLDG and 'no' for the NEWG and NONG). The minumum possible score was 0 and the maximum possible score was 30.

The total scores of the subjects indicate that most subjects were functioning significantly above chance. As can be seen in the frequency table (Table 9) for the total correct recognition 75% of the subjects scored significantly above chance (18 correct sequences out of the 30 sequences is 60% correct which is significantly above chance for this type of task).

A three way ANOVA was carried out for the total correct scores of 115 subjects (Appendix C, Table 22). The only factor that was significant was: condition [$F(3,91)=4.91$, $p<0.002$]. There was no significant age effect nor was there any sex effect or significant interactions.

The average score for each age group was at least 19 correct recognitions which significantly exceeds chance. The mean total correct recognition scores for the three age groups was: Group 1=19.45, Group 2=19.57, and Group 3=21.01.

Table 9

Frequency distribution (in percent) 15 or more and 18 or more total correct by age and condition

Experiment 2

N=115

Age Total Correct	ImS N=30	Condition ImM N=28	ExS N=27	R N=30	Mean
5 - 7					
18 or more	70.00	90.00	70.00	50.00	70.00
15 or more	90.00	90.00	90.00	90.00	90.00
9 - 11					
18 or more	70.00	90.00	87.50	70.00	78.40
15 or more	100.00	100.00	100.00	100.00	100.00
12 - 14					
18 or more	90.00	100.00	70.00	80.00	89.20
15 or more	100.00	100.00	100.00	90.00	97.00
Mean Condition					
18 or more	83.33	92.85	75.00	66.75	78.30
15 or more	96.67	96.43	96.43	92.85	95.00

Note that 18 or more correct is significantly above chance and 15 or more correct is at least half correct.

The effect of condition was due to a significant difference between the ImS and R condition [F(1,91)=5.09, p=0.02]. There were no significant differences in the total recognition scores of the ImS condition as compared with each of the other two structured conditions [ImS vs. ImM - F(1,91)=2.26, p=0.13; ImS vs. ExS - F(1,93)=.04, p=.83]. For more details see Section B.

A.2.2. Correct recognition for the different types of sequences

For each subject the total number of correct answers to each type of sequence (OLDG, NEWG and NONG) was computed. A split plot with three between factors (condition, age and sex) and one within factor (type of sequence) ANOVA was carried out for the 115 subjects (Appendix C, Table 24). (For the 'type of sequence' factor a correction with a mutlivariate test was carried out, see experiment 1, p 48 for details.) The factors that were significant were: condition [F(3,91)=3.90, p=0.01], type of sequence (p<0.0001), and the interactions of condition with type of sequence (p<0.0001), and condition by age by sex [F(6,91)=2.39, p=0.03].

In order to learn more about the significant condition effect paired comparisons between the ImS condition and each of the other three conditions (ImM, ExS and R) were carried out. None of the three comparisons were significant (for more details see Section B and Table 14).

The significant effect of the type of sequence reflects a significant difference between the NONG and NEWG scores [F(1,91)=121.90, p<0.0001]. The NONG scores were significantly higher than the NEWG

Table 10

Mean percent of correct recognition - by age, condition and type of sequence

Experiment 2

N=115

Age	Type of sequence	Condition ImS	ImM	ExS	R	Mean
	OLDG	61.00	53.00	56.00	59.00	57.30
5 - 7	NEWG	57.00	68.00	59.00	63.00	61.80
	NONG	81.00	87.00	80.00	54.00	75.50
Mean	5 - 7	66.30	69.30	65.00	58.70	64.80
	OLDG	60.00	56.00	65.00	57.00	59.50
9 - 11	NEWG	50.00	63.00	50.00	65.00	57.00
	NONG	79.00	88.00	90.50	58.00	78.80
Mean	9 - 11	63.00	69.00	68.30	60.00	65.10
	OLDG	66.00	63.00	59.50	64.10	63.00
12 - 14	NEWG	61.00	72.70	53.33	71.00	64.50
	NONG	88.00	94.30	85.30	66.00	83.40
Mean	12 -14	71.70	76.80	66.00	66.70	70.30
Mean Condition		67.00	71.70	66.40	61.80	

scores. There was no significant difference between the OLDG and NEWG scores collapsed over all other factors [F(1,91)= 0.14, p=0.71].

Details about the condition x type of sequence interaction are found in Section B of the results. In general, the major source of the interaction was due to the difference between the structured conditions (ImS, ImM and ExS) and the random condition. In the structured conditions NONG was significantly higher than NEWG. In the R condition the opposite was true NONR was significantly lower than NEWR. As was the case in Experiment 1, the result NEWG<NONG in the structured conditions is taken as evidence of the activation of implicit processes which abstract the underlying grammar. This claim is reinforced by the opposite results obtained in the random condition. Since in the random condition with no underlying grammar to abstract there was no interference of the abstract knowledge of the grammar and therefore, NEWR scores were not lower than NONR scores.

The significiant interaction between condition, age and sex is due to a significant interaction of the latter two factors in the random condition. There was no significant interaction of age with sex in the structured conditions [ImS - F(2,91)=.48, p=0.62; ImM - F(2,9I)=0.21, p=0.81; ExS - F(2,91)=1.38, p=.25; R - F(2,91)= 6.88, p<0.01]. There was no a priori rationale for testing the source of the significaant interaction in the random condition and and it may be that no special significance should be attached to this result.

A.2.3. Confidence

The subjects were asked for a confidence rating for every sequence shown in Part II. There were three degrees of confidence: 0 - very confused; 1- a little confused, a little sure; and 2 - very sure. For each type of sequence the subjects' total confidence score was computed (range 0 - 20). In order to facilitate comparison a percentage score was computed:

$$\text{confidence score} = \frac{\text{total confidence}}{20} \times 100$$

A split plot with three between factors and one within factor ANOVA was carried out for the confidence scores of the 115 subjects (Appendix C, Table 25). The significant factors were condition [$F(3,91)=2{,}60$, $p=0.05$], type of sequence ($p<0.001$) and interactions of condition x type of sequence ($p<0.01$) and sex x age [$F(2,91)= 6.17$, $p<0.01$].

In order to learn more about the significant condition effect paired comparisons of the ImS condition with the other three conditions were carried out. None of the comparisons were significant. (see Section B for details).

The significant type of sequence effect reflects the same relationship that was found in the recognition scores: NEWG scores were significantly fewer than NONG scores [NEWG vs. NONG - $F(1,91)=4.27$, $p=0.04$] but in addition NEWG scores were also significantly lower than the OLDG confidence scores [$F(1,91)=11.96$, $p<0.01$] (see Table 11). This result was very similar to the results of the recognition scores in Experiment 1 and is in line with the abstraction of the underlying grammar claim, i.e., that the subjects' knowledge of the grammar makes rejecting the NEWG instances as unfamiliar more difficult than recognizing familiar OLDG. The mean confidence scores for the three types of sequences were: OLDG - 78.80%, NEWG - 73.75% and NONG - 76.60%.

The significant condition x type of sequence interaction is discussed in full in Section B. The major source of the effect reflects, as in the recognition scores for the three types of sequences, the difference between the structured and random conditions. In the structured conditions the confidence for the NEWG sequences is significantly lower than the confidence for the OLDG and NONG sequences. In the random condition, the confidence for the NEWR sequences is significantly higher than the confidence for the NONR sequences and significantly lower than the OLDR. Moreover the NONR scores are significantly lower than the OLDR scores, while there is no significant difference between the NONG and OLDG scores (see Table 11).

A.2.4. Summary of Part II

In part II there were significant effects of condition and type of sequence in the recognition scores and in the confidence scores. There were no significant effect of sex or age but there were two significaant interactions with age and sex.

Table 11

Mean confidence scores - by age,

condition and type of sequence

Experiment 2

N=115

Age	Type of sequence	Condition ImS	ImM	ExS	R	Mean
5 - 7	OLDG	71.00	73.00	86.50	82.50	80.25
	NEWG	75.00	72.50	84.50	68.50	75.12
	NONG	81.00	75.50	85.00	71.75	78.31
Mean	5 - 7	78.33	73.67	85.33	74.25	77.90
9 - 11	OLDG	80.50	89.50	71.25	72.50	78.44
	NEWG	74.50	75.00	70.42	78.00	74.60
	NONG	84.50	82.50	70.00	62.50	74.90
Mean	9 - 11	79.11	82.33	70.56	71.20	75.98
12 - 14	OLDG	75.75	76.25	83.62	75.75	77.84
	NEWG	66.75	72.17	80.62	66.50	71.75
	NONG	75.00	86.42	83.62	61.25	76.57
Mean	12 -14	72.50	78.28	82.62	67.83	75.31
Mean Condition		76.89	78.09	79.50	71.09	

For all the structured conditions (ImS, ImM and ExS) the recognition scores and confidence scores for the NONG sequences were higher than the NEWG sequences i.e., NONG>NEWG. For the random condition the NONR scores were lower than the NEWR scores. Moreover, NONG scores were higher than the NONR scores i.e. NONG>NONR.

B. Topical review of results

B.1. Effect of predisposition

The effect of predisposition is manifested in two comparisons: (1) between the ImS condition and the ExS condition and (2) between the first time and the second time the subject carried out each task.

B.1.1. Explicit versus implicit predisposition

Part I - In the acqusition phase the explicit predisposition had no significant effect on the number of trials to learn for any age group or for any other variables and their interactions. But note, that the general trend, contrary to expectations, was in the direction of a decrease in the number of trials required to reproduce the sequences correctly in the explicit condition.

The explicit predisposition did have a significant effect on the total time [$F(1,93)=5.34$, $p=0.02$] and there was also a significant interaction between instructions and age [$F(2,93)=4.01$, $p=0.02$]. The significant age effect was due to a large decrease in total time in the explicit condition for the 5-7 year old group (ImS - 26.9 min. vs. ExS - 18.9 min.). There was no significant difference in the total time of the older children: (1) for the 9-11 year olds - ImS vs. ExS - F(1,93)=0.26, p=0.61; (2) for the 12-14 year olds there was no interaction of condition with age [F(3,930=0,29, p=0.83] so a specific comparison between the ImS and ExS condition would be meaningless. The decrease in learning time in the ExS condition, which was especially strong for the youngest age group, was surprising and contrary to expectations.

There was no significant effect of instructions on the rate (total trials/total time) of reproduction. The trend was, again, contrary to expectation, in the direction of faster rates for the ExS condition.

Part II - There was no significant effect of instructions on the total correct recognition scores [F(1,91), 0.04, p=.83]. A split plot ANOVA (three between factors and one within factor) for the 57 subjects of the ImS and ExS condition was carried out for the percent of correct recognition of each type of sequence. There was no significant effect of instructions or interaction with instructions.

The only effect that the instructions had on the confidence scores was a significant instruction x age interaction [F(2,91)=2.97, p=0.05]. This effect is interesting since it reflects a significant difference between the middle age group as compared to the oldest and youngest age groups [5-7 vs. 9-11 F(1,91)=3.82, p=0.05; 12-14 vs. 9-11 F(i,91)=5.28, p0.02], while there was no difference in the confidence levels of the oldest and youngest age groups [F(1,91)=0.16, p=0.69]. The 9-11 year olds were more confident in the ImS condition, whilst the 5-7 and the 12-14 year olds were more confident in the ExS condition (see Table 12).

B.1.2. Summary and conclusions on the effect of explicit instructions

The results of the manipulation of instructions were disappointing. The effects of the explicit instructions were very weak. The three measures of Part I (total trials, total time and rate) indicate that the subjects found the ExS condition easier, or at least no different than the subjects in the ImS condition. There is no indication from these measures that the subjects were trying to find or test various hypotheses about the rule system, since they did not spend any more time with the sequences then the ImS subjects. In fact, the ExS subjects' rate was faster, i.e. they spent less time with each sequence then the ImS subjects. Therefore, it seems that the failure in producing any significant effect of instructions on the recognition scores may be due to a failure in creating an explicit predisposition in the subjects. In other words, the children who were informed that the materials were constructed according to some rules of a game which they should try and discover to facilitate their reproduction did not translate these instructions into an active search or strategy of 'cracking the code' or finding some rules. Consequently, there was no interference or digression as a result of the explicit instructions.

This conclusion is reinforced by the subjects' answers to a post-experimental question - "What were the rules of the game?" Many of

Table 12

Percent of correct recognition and confidence scores by type of sequence for the ImS and ExS condition

Experiment 2

N=115

Age	Type of sequence	% recognition ImS	% recognition Exs	Confidence score ImS	Confidence score Exs
	OLDG	61.00	56.00	71.00	86.50
5 - 7	NEWG	57.00	59.00	75.00	84.50
	NONG	80.00	80.00	81.00	85.00
Mean 5 - 7		66.00	65.00	78.33	85.33
	OLDG	60.00	65.00	80.50	71.25
9 - 11	NEWG	50.00	50.00	74.50	70.42
	NONG	79.00	90.50	84.50	70.00
Mean 9 - 11		63.00	68.30	79.11	70.56
	OLDG	66.00	59.50	75.75	83.62
12 - 14	NEWG	61.00	53.33	66.75	80.62
	NONG	88.00	85.30	75.00	83.62
Mean 12 -14		71.70	66.00	72.50	82.62
Mean Condition		67.00	66.40	76.89	79.50

the subjects in the ExS condition simply answered that they didn't know or when probed, the subjects said that the colors and shapes could appear in any order or pattern and there were no rules. Other subjects gave a list of procedural rules. For example:

Subject # 75 (8;11, male) answered: "I suppose, try to remember the shape cards and put them out."

Subject # 82 (14;10, male): "You have to match them with the right side up, that's all I could think of."

Subject # 75 (7;0, female): "The rules were to remember the cards so you could put them down and not get them wrong."

A few of the subjects did seem to pick up our intentions - see Appendix B for an example.

The subjects in the implicit and explicit conditions, were probed for specific rules, such as, 'which of the shapes could or couldn't appear at the left side (beginning) of the pattern?' It is interesting that the subjects' reply to these probes was often correct but the answer was often a suprise to the child. In other words, when the experimenter asked the child a general question, like the one above, the subjects usually replied that all the shapes could appear in a particular position. Yet when the experimenter probed more deeply and asked about each shape separately the subject came up with the right answer and with some surprise he revised his answer when the general question was asked again.

B.2. Effect of repetition

Part I - As in Experiment 1, reproduction was easier and quicker the second time as measured by total trials, total time and rate (see Table 13). Separate ANOVAs were carried out for each of these measures with repetition as a within subject factor. For each measure repetition was a significant factor. (1) For total trials to learn - $F(1,93)=33.74$, $p<0.0001$. In addition there was an age x repetition interaction [$F(2,93)=5.51$, $p=0.01$]. (2) For total time - $F(1,93)=68.22$, $p<0.0001$. (3) For rate - $F(1,93)=12.75$, $p<0.001$. There was also an interaction of age x repetition [$F(2,93)=6.43$, $p<0.01$].

Part II - There was a significant increase in the total correct recognition scores the second time [$F(1,91)=6.67$, $p=0.01$]. The mean total correct recognitions for the 1st time=20.01 and the 2nd time=20.88. There was no significant interaction of repetition with the other three factors (condition, age and sex) on the total correct recognition measure.

For the percent of correct recognition of the different types of sequences the effect of repetition is quite complex. A split plot ANOVA with three between factors and two within factors was carried out. In general, there was a significant effect of repetition [$F(1,91)=6.01$, $p=0.015$] and a significant age x type of sequence x repetition interaction ($p=0.02$). When the structured conditions were analyzed separately there was no significant effect of repetition [$F(1,91)=2.89$,

Table 13

Effect of repetiton on acquisition

total trial, total time and rate

Experiment 2

N=117

	Acquisition measure		
Group	Total Number trials	Total time (min.)	Rate (# trial/ min.)
5 - 7			
1st time	31.95	21.10	1.48
2nd time	26.18	20.45	1.42
9 - 11			
1st time	22.28	10.59	1.93
2nd time	20.56	11.30	2.22
12 - 14			
1st time	19.02	8.21	2.21
2nd time	16.84	7.92	2.46

p=0.09]. However, in the random condition there was a significant improvement with repetition [F(1,91)=4.01, p=0.045]. The improvement in the random condition was a result of a significant improvement in the recognition of the NONR sequences the second time [F(1,91)=5.58, p=0.02].

The complex interaction age x type of sequence x repetition reflects a significant difference in the OLDG scores of the youngest age group as compared to the two older age groups [F(1,91)=4.68, p=0.03]. The 5-7 year olds scored slightly lower on the OLDG sequences the second time while the older subjects improved on their OLDG scores. In addition, the oldest children's scores were significantly different than the two younger groups on the NEWG and NONG sequences [F(1,91)=6.46, p=0.01]. The 12-14 year olds did slightly worse on these two types of sequences the second time while the younger subjects improved on the NEWG and NONG sequences the second time.

A closer look at the effect of repetition within each condition shows that (see Table 14):

(1) <u>ImS condition</u> - there was a significant effect of repetition [F(1,91)=4.01, p=0.045] and a significant age x repetition interaction [F(2,91)=4.04, p=0.02] due to a decrease in the NEWG and NONG scores of the 12-14 year olds [F(1,91)=3.67, p=0.055].

(2) <u>ImM condition</u> - there was <u>no</u> improvement with repetition [1st

Table 14

Effect of repetition on percent of correct recognition:

condition, age and type of sequence

Experiment 2

N=115

Age	Type of sequence	ImS 1st	ImS 2nd	ImM 1st	ImM 2nd	ExS 1st	ExS 2nd	R 1st	R 2nd	Mean
	OLDG	61	52	53	47	56	57	59	59	56
5 - 7	NEWG	57	77	68	73	69	68	63	69	67
	NONG	81	96	87	87	80	87	54	69	80
Mean	5 - 7	66	75	69	69	65	71	59	66	68
	OLDG	60	70	56	63	60	65	57	58	62
9 - 11	NEWG	50	61	63	57	55	58	65	71	59
	NONG	79	88	88	80	93	88	58	70	80
Mean	9 - 11	63	73	69	67	68	67	60	66	67
	OLDG	66	74	63	78	60	70	63	62	67
12 - 14	NEWG	61	51	75	59	54	66	71	76	64
	NONG	88	76	94	91	85	84	66	64	81
Mean	12 - 14	72	67	77	76	66	72	67	67	71
Mean Condition		67	72	72	71	66	70	62	66	

71.70%, 2nd - 70.90%; F(1,91)=0.10, p=0.75]. This lack of effect of repetition is consistent for each of the age groups [F(2,91)=0.03, p=0.95].

(3) ExS condition - there was no significant effect of repetition [F(1,91)=1.67, p=0.19]. {The youngest and oldest age groups improve with repetition. The middle age group did not improve with repetition. This is true for all three types of sequences, this effect is not significant [F(1,91)=1.61, p=0.0.21].}

(4) R condition - there was a significant effect of repetition [F(1,91)=4.01,p=0.045] and there was no interaction of repetition with age [F(2,91)=.74, p=0.48]. Yet a closer look at the data shows that there is only an improvement in the the younger age groups (5-7 & 9-11) and no change in the oldest age group (12-14).

For the confidence scores a split plot ANOVA with three between factors and two within factors was carried out. There was no significant effect of repetition. The only significant interaction with repetition was a four way interaction of condition x age x sex x repetition [F(6,91)=2.44, p=0.03].

Conclusions

In general, while it is clear that repeating the reproduction task resulted in improvement in the acquisition phase, the effect of repetition on the recognition task is ambiguous. The subjects' total recognition scores did in fact improve, but a more detailed breakdown of recognition according to the three types of sequences presents an equivocal picture. Therefore, it is possible that the effects are a result of circumstantial variability or a mixture of factors that are too complex to separate within the present experiment.

B.3. 'Analogical' versus 'abstract' processing

In order to find out more about the effect of analogical (specific memory) versus abstract processing two comparisons were carried out: (1) between the ImS and R conditions and (2) between the Structured conditions (ImS, ImM and ExS) and Random condition.

In order to avoid redundancy the second comparison will not be presented since it essentially reflects the same picture. When the results of the Structured vs. Random comparison are of interest or different from the first comparison these results will be presented within the ImS vs. R comparison.

ImS versus the R condition

Part I - Reproducing the sequences correctly required more trials and more time in the R condition. The difference between the R condition and the ImS condition was not significant for the total trials measure [f(1,93)0.81, p=0.37] and was not significant for the time measure [F(1,93)=0.79, p=0.38] but was significant for the rate measure

[F(1,93)=3.65, p=0.05]. For the Structured versus Random conditions comparison there were significant differences on all three measures [total trials: F(1,93)=3.25, p=0.07; total time: F(1,93)=8.89, p<0.004; rate: F(1,93)=10.71, p,0.002] and the Random condition was harder (more trials and slower rate of reproduction) and took a longer time to complete. (See Table 6, p. 68 for mean total trials.)

On the time measure there was a significant interaction of age x condition (see Section A.1.2.). This interaction reflects a differential effect of structure within each age group: (1) for the youngest and oldest age children there were no significant differences between the Structured (ImS) and non structured (R) conditions [5-7: F(1,93)=1.60, p=0.21; 12-14: F(1,93)=0.67, p=0.42] but (2) for the middle age group there was a significant effect of structure and these children required a significantly a longer time to complete the reproduction in the random condition [F(1,93)=4.14, p=0.04]. See Table 7, (p. 70) for the mean time measure for each age group.

Part II - In the total correct scores, the subjects in the R condition did significantly worse than the subjects in the ImS condition [Mean total correct recognition R=18.33, ImS=20.20; F(1,91)=5.09, p=0.02].

A split plot (3 between factors and one within factor) ANOVA for percent of correct recognition for each type of sequence was run for the

60 subjects in the ImS and R conditions. The factors that were significant were: type of sequence ($p<0.001$) and interaction of condition x type of sequence ($p<0.0001$) and condition x age x sex [$F(2,48)= 5.25$, $p<0.01$]. In addition, in the Structured vs. Random comparison there were also significant effects of condition [$F(1,103)=8.8$, $p<0.01$] and interaction of age x sex [$F(2,103)=4.56$, $p=0.01$].

In general the ImS subjects scored higher than the R subjects (R = 61.90% vs. ImS = 67.50% mean correct for each type of sequence) though the difference was not significant, as indicated above. The difference between the Structured and Random conditions was significant (Structured - 68.90% vs. Random - 61.90%).

The 'condition x type of sequence' interaction reflects the intrinsic difference between the two conditions. In the ImS condition - NONG>OLDG>NEWG (paired comparisons between each two types of sequences show that only OLDG is not significantly different from NEWG). In the Random condition NEWR>NONR>OLDR (the difference between each type of sequence is significant). The F tests for the paired comparisons and the means of percent correct for each type of sequence for the two conditions are presented in Table 15.

Table 15

Mean percent correct recognition of the three types of sequences:ImS, R and Structured* conditions

Experiment 2

Type of sequence	ImS N=30	Condition Structured* N=85	R N=30
OLDG	62.30	59.30	60.00
NEWG	56.00	60.50	66.30
NONG	82.70	86.10	59.30
Mean	67.00	68.60	61.90

$$^{*}\text{Structured} = \frac{\text{ImS} + \text{ImM} + \text{ExS}}{3}$$

Planned comparisons

ImS: OLDG vs. NEWG - $F(1,48)=1.16$, $p=0.29$
NEWG vs. NONG - $F(1,48)=87.37$, $p<0.0001$

R: OLDR vs. NEWR - $F(1,48)=5.47$, $p<0.05$
NEWR vs. NONR - $F(1,48)=6.02$, $p<0.01$

ImS vs. R: OLDG(R) - $F(1,48)=0.29$, $p=0.66$
NEWG(R) - $F(1,48)=3.72$, $p=0.056$
NONG(R) - $F(1,48)=31.11$, $p<0.0001$

Structured vs. R: OLG(R) - $F(1,103)=0.01$, $p=0.88$
NEWG(R) - $F(1,103)=1.60$, $p=0.21$
NONG(R) - $F(1,103)=58.40$, $p<0.0001$

In other words, a comparison of the subjects' performance within the two conditions indicates that in the ImS condition (and in the Structured conditions, as well) the subjects scored highest on the NONG sequences and significantly lower on the NEWG sequences. While in the Random condition the reverse was true - the subjects did best on the NEWR sequences and scored significantly lower on the NONR sequences.

Moreover, a comparison between the two conditions indicates that the subjects' recognition scores for the NEWR sequences in the R condition was significantly higher than the recognition scores of the subjects in the ImS condition for the NEWG sequences [$F(1,48)=3.72$, $p=0.056$] whereas their recognition of the NONR sequences was significantly lower than the recognition NONG sequences by the subjects in the ImS condition [$F(1,48)=31.11$, $p<0.0001$].

The 'condition x age x sex' interaction reflects a significant interaction of age x sex in the Random condition [$F(2,48)=6.63$, $p<0.01$]. There is no interaction of age x sex in the ImS condition [$F(2,48)=0.45$, $p=0.65$]. Within the Random condition there was a significant interaction with sex only within the youngest age group.

The confidence scores reflect the same relationship that was found for the recognition scores:

(1) confidence for the R condition was lower than for the ImS condition (R - 71.09% vs. ImS - 76.89%). The difference was not

significant [$F(1,91)=3.39$, $p=0.065$] but the difference was significant for the Structured vs. Random comparison [$F(1,91)=7.33$, $p<0.01$];

(2) there was a significant interaction between condition and type of sequence ($p<0.01$). This interaction reflects:

(a) for the *ImS* condition the relation between the confidence scores for the three types of sequences was - NONG>OLDG>NEWG. The confidence for the NEWG sequences was significantly less than the confidence for the OLDG and NONG sequences. There was no significant difference between the OLDG and NONG on the confidence scores;

(b) for the *R* condition - OLDR>NEWR>NONR. In other words, for the Random condition the opposite relation exists between the new sequences - NEWR is significantly higher than NONR; It is interesting to note that the subjects' recognition scores for the OLDR sequences were lower than for any other sequence, yet they were most confidence of their response to the OLDR sequences.

(c) the *ImS vs. R* comparison indicates that NONG>NONR (same as recognition) *but* NEWR<NEWG (contrary to the performance scores).

Conclusions

In general, the results of the manipulation of structure were in line with the expectations. The ImS vs. R comparison and the Structured vs. Random comparison both indicate that:

(1) Acquisition of structured materials was easier and quicker.

(2) Recognition and confidence scores for the ImS condition manifested clear evidence of implicit processing of the underlying structure and were significantly different from the recognition and confidence scores in the R condition in which there was no underlying structure.

(3) There was no difference between the conditions on the OLD sequences. The difference between the two conditions was in the relationship between NEW sequences. In the ImS (Structured) condition - NEWG<NONG while in the R condition - NEWR>NONR.

(4) As expected NEWR>NEWG though the difference was not significant.

(5) There were no significant age and sex effects. There was a significant interaction of 'condition x age x sex' which was due to a significant interaction in the R condition.

B.3. Contextual effects

The effect of context (manipulating the materials used in producing the sequences) is manifested in the comparison of the ImS condition with the ImM condition.

Part 1 - Learning was easier (ImM -22.79 trials vs. ImS - 24.73 trials) and quicker (ImM - 12.93 min. vs. ImS - 15.93 min.) with the meaningful stimuli. The difference did not reach significance for the total trials measure [F(1,93)=1.61, p=0.20] but was significant for the time measure [F(1,93)=4.60, p=0.03]. There was no difference in the rate of reproduction between the ImS and ImM condition.

A closer look at the results of Part I shows that the major facilitating effect of the 'meaningfulness' of the stimuli was concentrated in the 5-7 year old age group and there were no significant differences between the two conditions for the 9-11 and 12-14 year olds. The total number of trials to reproduce the sequences correctly was lower for the youngest children on the ImM condition (ImM - 22.79, ImS - 24.73). Their total time was also significantly lower in the ImM condition [F(1,93)=13.69, p<0.01; ImM - 19.00 min. vs. ImS - 26.90 min.]. There was no significant difference on either measure for the two older age groups. (See Table 6 and Table 7.)

Part II - The total correct scores were higher for the ImM condition, but the difference is not significant [F(1,91)=2.26, p=0.13].

For the percent of correct recognition for each type of sequence a split plot (three between factors and one within factors) ANOVA was run for the 58 subjects of the two conditions. There was no significant effect of condition or interaction with condition.

A comparison of the ImM and ImS condition on the percent of correct recognition (see Table 16) of the OLDG and NEWG sequences reveals an

Table 16

Mean percent correct recognition by age and type of sequence in the ImS and ImM conditions

Experiment 2

Age	Type of sequence	Condition ImS N=30	 ImM N=28
5 - 7	OLDG	61.00	53.00
	NEWG	57.00	68.00
	NONG	81.00	87.00
9 - 11	OLDG	60.00	56.00
	NEWG	50.00	63.00
	NONG	79.00	88.00
12 - 14	OLDG	66.00	63.00
	NEWG	61.00	72.70
	NONG	88.00	94.30
Mean Condition		67.00	71.70
Mean OLDG		62.30	57.40
Mean NEWG		56.00	67.90
Mean NONG		82.70	89.80

interesting relationship: (1) For the ImS condition - OLDG scores are higher than NEWG scores. In other words, it seems that the abstra ction of the underlying grammar makes rejecting the NEWG sequences more difficult than recognizing the OLDG. (2) For the ImM condition - the opposite relation exists, the OLDG scores are lower than the NEWG scores. (3) The NEWG scores in the ImM are significantly higher than the NEWG scores of the ImS condition [F(1,46)=5.34, p=0.02].

The difference in the relationship between the OLDG and NEWG in the ImS vs. the ImM condition does not reach significance [F(2,46=3.56, p=0.06]. Nevertheless, the general direction does suggest that there is less abstraction of the underlying grammar (less interference in the NEWG sequences) in the ImM condition. Moreover, the difference in the relationship between the OLDG and NEWG in the two conditions is consistent for each of the three age groups (see Table 16).

There was no difference between the two condition on the confidence scores.

Conclusions

The effects of the 'meaningfulness' of the stimuli were in the expected direction. Meaningfulness of the material facilitated acquisition. This effect was especially evident in the 5-7 yr. olds who were having, as expected, the hardest time with the reproduction task.

The recognition scores of the ImM condition reflect a decrease in the degree of abstraction of the underlying structure (higher NEWG scores) in the ImM condition. There was a slight decrease in the OLDG scores in the ImM condition which was offset by the increase in the NEWG scores, therefore the decrease in abstraction was not reflected in a significant increase in the total recognition. There were no age or sex effects due to the added meaningfulness of the material.

B.4. Developmental differences in implicit processing

One of the most striking results of both experiments was that there were no significant age differences in Part II for any measure (total correct, percent correct and confidence). The younger children seemed to abstract some of the underlying grammar just as did the older children (and adults). Yet there were a number of significant interactions of age with other variables (condition, type of sequence, repetition and sex). The picture emerging from these interactions is complex and is far from being clear cut. The data seem to suggest that on many of the measures the 5-7 year olds are more similar to the 12-14 year olds than to their nearest age group (9-11).

In order to learn more about these age differences in the nature of the implicit processing an additional analysis was carried out. This analysis is based on a comparison of the subjects' actual performance to their performance assuming an extreme abstractionist model.

According to an extreme abstractionist model, the subject does not retain any specific memory of the sequences reproduced in Part I. The only memory the subject has is for some abstract representation of the grammar. When the subject is presented with the recognition task, the subject cannot distinguish between old and new grammatical sequences and he will say 'yes' (to the recognition question) for both types of sequences. The total number of times the subject says 'yes' to the new grammatical sequences equals the total number of new grammatical sequences less the number of times he said 'no' to these sequences i.e., 10 - NEWG.

In this manner it is possible to compute the difference between two total scores for each subject. The first total score is the total correct recognition score and it equals OLDG + NEWG + NONG (i.e., the total number of yeses to the old grammatical sequences plus the total number of noes to the new grammatical and nongrammatical sequences). The second total score is the total recognition score given the extreme abstractionistic model and it equals OLDG + (10 - NEWG) + NONG (i.e., the total number of yeses to the old grammatical and new grammatical sequences plus the total number of noes to the nongrammatical sequences). If we subtract the second total score from the first we get a measure which reflects a comparison between the subjects' actual performance and performance given an extreme abstractionist model.

The difference between the two total scores, the comparison score, equals 2NEWG - 10. If the number of 'no' answers equals the number of 'yes' answers the subject gave to the new grammatical sequences than NEWG=5 and the comparison score (the difference between the two total scores) equals exactly zero. If the number of 'no' answers is greater then the number of 'yes' answers (NEWG>5) then the comparison score is greater than zero, and vice versa, if the number of 'no' answers is smaller than the number of 'yes' answers (NEWG<5) then the comparison score is smaller than zero. Thus the higher the comparison score the less interference there is of abstraction of the grammar and the greater the specific memory of the subject. Contrariwise, the lower the comparison score the greater the degree of the effect of the abstraction of the underlying grammar.

A three way ANOVA for the comparison scores was run for the 115 subjects. The significant factors were: condition [$F(3,91)=2.66$, $p=0.05$) and the interaction of condition by age by sex [$F(6,91)$, $p<0.01$]. As in all recognition measures there was no simple significant age effect.

As expected the comparison scores for the Random condition (in which there was no possible interference of the abstraction of the underlying grammar) were significantly higher than any of the structured conditions [ImS vs. R: $F(1,91)=5.29$, $p=0.02$; Structured vs Random: $F(1,91)=5.03$, $p=0.03$; See Table 17]. Within the Structured conditions, there were no significant differences, though the mean scores for the conditions suggest that there might have been, as expected, a decrease

Table 17

Comparison scores for correct recognition

by age, sex and condition

Experiment 2

N=115

Age Sex	Condition ImS	 ImM	 ExS	 R
5 - 7: Mean	1.40	3.60	2.30	2.60
Females	1.20	2.40	4.20	4.80
Males	1.60	4.80	0.40	0.40
9 - 11: Mean	0.00	2.30	0.00	4.20
Females	0.80	2.00	2.00	1.60
Males	-0.80	2.60	-2.00	6.80
12 - 14: Mean	2.30	2.53	0.85	4.20
Females	3.00	6.40	-0.80	1.20
Males	1.60	-1.33	2.50	7.20
Mean Condition	1.23	2.81	1.05	3.67

in the degree of abstraction as a result of the change in the stimuli from simple to meaningful [ImS - 1.23, ImM - 2,89; ImS vs. ImM: F(1,91)=2.11, p=0.146] and contrary to expectations there was no significant effect of the instructions [ImS - 1.23, ExS - 1.05; ImS vs. ExS: F(1,91)=0.03, p=0.85].

As in all other analyses carried out on the recognition scores there was no simple age effect, nor an age x condition interaction (nor were there any age effects within each of the condition analysed separately). Therefore, one can only look at the results for suggestions but additional research will be necessary to test these suggestions. The results of the structured conditions, especially the ImS condition seem to suggest that the 5-7 year olds are more similar to the 12-14 year olds than their nearest age group (9-11). In Table 21 the mean comparison scores for the significant interaction of 'condition x age x sex' are presented. The resultant picture presented in Table 21 is obfuscated by the sex interaction. All that can be clearly stated at this point is that the trends suggest that there may be some indication that in the quality of implicit processing there exists a 'U' shaped relation between the three age groups.

GENERAL CONCLUSIONS AND DISCUSSION

The results of the first experiment were replicated in the second experiment. The three principal conclusions of both experiments are:

(1) children and adults implicitly abstract underlying grammar.

(2) the implicit processing, at least in this type of situation, does not exhibit any developmental changes.

(3) recognition tasks can be effectively utilized in experimental situations investigating the activation of implicit processes.

Experiment 2 was also designed to address a number of additional issues emerging from the current implicit learning research. Three manipulations were applied to investigate these issues. The results of the three manipulations in Experiment 2 were mixed:

A. Effect of instructions - It was not possible to ascertain the effect of an explicit predisposition. The results of the acquisition phase (which are corroborated by the post-experimental responses of many of the subjects) raise serious doubts whether many of the subjects in the explicit instructions condition were, in fact, performing under an explicit predispostion.

B. Effect of materials - The effect of the manipulation of the materials used in producing the sequences was not strong but was clearly in the expected direction. In the 'meaningful' material condition learning was easier (especially in the youngest age group), whereas there was a decrease in the level of abstraction of the underlying grammar as indicated by the recognition performance of the subjects in that condition.

C. Structure - The effect of structure was unequivocal and in the predicted direction. In Part I, acquisition was more difficult in the Random condition. The difficulty was reflected in all measures.

In Part II, The total recognition scores were lower in the Random condition reflecting the difficulty the subjects had in the Random condition. The percent of correct recognition of the three types of sequences encapsulate the differences between the Structured and Random conditions. Within the Structured conditions the recognition scores of the new grammatical and nongrammatical sequences manifest the effect of the knowledge of the underlying structure. Within the Random condition the recognition scores of the new random and the nonrandom sequences manifest the effect of specific memory of the random items of Part I. A comparison between the Structured and the Random conditions shows, as expected, the effect of the knowledge of the underlying grammar in the Structured conditions which facilitates correct recognition of nongrammatical sequences (as compared to nonrandom sequences) and interferes with the correct recognition of new grammatical instances (as compared with the new random instances).

A look at each of the above conclusions raises many new questions and issues. Some cannot be answered without additional research, or are beyond the scope of this dissertation, while others require a reexamination of the assumptions of this study, and in some cases a reanalysis of part of the data. A number of issues emerge:

(1) What kind of "abstraction" knowledge have our subjects gained as it is manifested in the testing phase?

(2) How effective and sensitive are recognition tasks for implicit processing research? Since no developmental differences were found in either experiment, and no effect of instructions was found in the explicit condition (ExS) in Experiment 2, the question more specifically is: What role, if any, did the use of a recognition task play in producing these negative results?

(3) What is the relationship between the acqusition task (Part I) and the testing task (Part II)?

(4) Why are the effects of the materials manipulation so weak?

(5) Is it possible that there exist different <u>types</u> and <u>roles</u> for implicit processes which may account for the lack of developmental differences found in this research?

A. The nature of the subjects' learning

The levels of correct recognition exhibited by the subjects for the different types of sequences were suprising to a certain extent. In both experiments, for all age groups and in all the structured conditions, subjects' recognition scores clearly exhibit the effects of the abstraction of the underlying grammar. Subjects found it easier to reject the NONG (nongrammatical) sequences then the NEWG (new grammatical) sequences. In addition, in Experiment 1 and in the control (ImS) condition of Experiment 2, the OLDG (old grammatical) sequences were recognized correctly (subject says 'yes') significantly more then the correct rejection (subject says 'no') of NEWG sequences. These results are consistent with the expectations (see Table 3, p. 49 and Table 10, p.76). There is, however, an inconsistency in the level of performance for the different types of sequences — the level of performance of the OLDG and NEWG was relatively (and significantly) lower (around 50-60%) then the level of performance for the NONG sequences (around 75-85%).

This discrepancy in the subjects' performance may be related to the complementary relationship between acquiring specific memory and acquiring abstract memory, as was discussed in the introduction. In the present experiments the subjects were given relatively short learning experiences. It is plausible that they acquired more abstract knowledge than specific memory for the instances. In this case, the abstract knowledge would be helpful in rejecting sequences which violated the grammar, while memory for specific instances would not be sufficient to supplement the abstract knowledge in recognizing old grammatical or in rejecting new grammatical sequences. This conjecture is also consistent with the levels of performance in the random (R) condition of Experiment 2 (see Table 10, p. 74 and Table 15, p. 94). Only specific memory was possible in the R condition (since there was no underlying grammar to abstract) and the level of performance for all of its sequences was at the 50-60% level.

There are a number of experimental manipulations which increase the subjects' specific memory that could be undertaken in order to test this explanation. For example, the learning of the subjects could be reinforced by repeating the learning phase before the testing phase; or the learning task could be changed to a paired associate learning task that has been shown by Reber & Allen (1978) to be more conducive to specific memory.

B. Use of a recognition task

Since by definition the activation of implicit processes can only be accessed indirectly, the choice of a testing task for the present type of study is especially critical and problematic. Any problems inherent in the specific task chosen could easily mask or distort the evidence. Of all the possible tasks a recognition task was chosen. There are two questions that this choice raises. The first is whether the choice of a memory task is consistent with the aim of this research, especially given the previous use of grammaticality judgments. The second is whether the choice of a recongition task is an appropriate task given the developmental perspective of the study.

B.1. Memory versus grammaticality judgments

The first question has already been answered to a certain extent by the research itself. The recognition task, generally considered appropriate for a wide age range, indeed proved to be clearly understood and easy to administer to the youngest as well as oldest subjects. In addition, the recognition scores for the different types of sequences did consistently detect the effect of abstraction (implicit processing) of the underlying structure for all age groups, in both experiments, whenever there was a structure to abstract.

Yet the question of wheter recognition indexes the same process as grammaticality judgments still remains. If we could find a way of introducing the notion of grammaticality to very young children would this be a more direct measure of implicit processing, and therefore a preferable method with greater construct validity? The answer is not straightforward. If the aim of the research is to access tacit knowledge acquired through implicit processing then both measures are valid. In fact, the existence of two different measures of the same outcome strengthens the case for claiming that the knowledge and processes do indeed exist. On the other hand, if the issue is whether the subjects can in some way actively participate in presenting evidence for the existence of implicit processing then grammaticality judgments are thus far the only measure of choice.

In general, at this early stage of our knowledge about implicit processes, the more types of measures and tasks available, the greater will our confidence be in the existence of implicit processes. Moreover, the existence of several methods enhances our efforts to access, study and 'unpackage' these elusive processes.

B.2. Recognition tasks and developmental differences

In designing developmental research there are some unique problems that must be taken into consideration in selecting tasks so that they may best capture the effects of the experimental manipulation. In particular, the tasks must be sensitive enough so that the experimental effects, if they exist, will be manifested in the youngest through the oldest age groups. In addition, any task which is known in itself to exhibit developmental differences will be suspect of interacting or interfering with the expression of the effects of the experimental manipulations.

Developmental data has usually indicated that recognition skills in young children are quite impressive and stand in marked contrast to their recall skills (Kail & Hagen, 1982). Moreover most of the age-related improvements usually found have been related to recall rather than recognition (see Perlmutter & Lange, 1978 for review). Hence, selecting a recognition task ensures that even the very young children will be competent at the task and therefore, if there should be any developmental differences found they can be attributed to the experimental manipulations and not to any distortion caused by the testing task.

The above considerations are only one side of the argument; there is still another possibility. Perhaps the fact that recognition tasks show few developmental changes is due to their insensitivity to developmental differences. This arguement can be rejected both on current theoretical as well as empirical grounds. Theoretically, [see Perlmutter & Lange (1978)] recognition is conceived as a very early development which is a necessary component in any knowledge acquisition. Hence, the lack of developmental changes in recognition are not due to an insensitivity of the recognition tasks but are a true reflection of the existence of recognitory skills in the very young. In addition, empirical evidence shows that developmental and other differences can be found in recognition performance. But in most cases, a closer look at these differences reveals that they (except for children younger than 4) are the result of age related differences in information pickup, acquisition or acquired world knowledge rather than a result of fundamental changes in the operation of memory. If this is the case, then recognition tasks are ideal for the purpose of detecting developmental differences in implicit processing.

C. The relationship between the reproduction and recognition task

The present study was divided into two parts. In Part I, the acquisition phase, subjects performed a reproduction task. It is during this phase, according to our model, that the implicit processes were activated. In Part II, the testing phase, subjects performed a recognition task. In this phase, according to our model, the testing tasks reflect the tacit knowledge acquired through the implicit processing of Part I.

In both experiments there were highly significant age differences in Part I and no significant age differences in Part II. The question is: Can the age differences found in Part I be attributed to developmental differences in implicit processing? The answer is a qualified no. Performance in the reproduction task used in Part I calls upon the use of strategies and other mnemonic devices which, according to our present knowledge, are not yet available to the youngest subjects. Thus, age differences would be expected in this task regardless of whether implicit processing had taken place. And indeed, in the random condition the same age effects were found as in the structured conditions. Therefore, any developmental changes in implicit processing cannot be partialled out from the other developmental differences in mnemonic skills used in Part I and thus only the data of Part II are useful for assessing developmental changes in implicit processing.

It maybe that at the testing phase (Part II) it is too late to find any developmental differences in implicit processing. In other words, the lack of any age effects in Part II may reflect the absence of developmental differences in the tacit knowledge acquired, although there were qualitative differences in the implicit processing that led to this knowledge. The present research was not designed so that this hypothesis could be tested, but future studies might address this issue.

There is another question about the relationship between Part I and Part II which is easier to test: How do the erroneous reproductions of the learning material affect the subjects' learning? The subjects, especially in the youngest age group, are exposed not only to the learning set but to their own erroneous reproductions of the learning set. Therefore, those subjects who make many errors actually go through a very different learning experience than those subjects who make few errors. Empirically this question is easy to study (although the underlying question still remains - why some subjects require more trials than others). The subjects in each age group of the Structured conditions (ImS, ImM and ExS) were divided into three groups according to the total number of trials they required for reproducing the learning set correctly: (1) Most - those subjects who required much more than the mean number of trials for their age group. (2) Average - those subjects who performed at mean level for their age group. (3) Least - those who were much below mean for their age group. Two extreme groups - most and least were selected from each age group, creating a new sample. This sample had 36 subjects from the three age groups. The results of the analysis of this sample can inform us about the relationship between the reproduction performance in Part I and the recognition scores of Part II. It should be noted that compared to the youngest age group, in the older age groups the disparity between the Most and Least subjects' performance in Part I was much smaller and there were fewer subjects performing at the Most and Least levels. See Table 18 for details.

A split plot ANOVA with two between factors - age and performance in Part I (most - least) and one within factor - type of sequence - was carried out for the percent of correct recognition of the three types of sequences. The significant factors were type of sequence ($p<0.0001$) and interaction of age x performance [$F(2,30)=3.42$, $p=0.04$] and age x performance x type of sequence ($p<0.03$). For marginal cell means see Table 18.

There were no significant differences in the performance of the two older groups. On the other hand, there were significant differences in recognition found between the Most and Least subjects in the youngest age group. This is an interesting result since for this age group, as stated above, the disparity between the Most and Least subjects' performance in Part I was the largest.

For the 5 - 7 age group, a comparison between the Most Group and the Least Group shows that:

Table 18

Mean percent correct recognition for sample based on performance in Part I by age, performance and type of sequence

Experiment 2

N= 36

Age	Type of sequence	Performance Part I: Least N=18	Performance Part I: Most N=18
5 - 7 [a] N=16	OLDG	48.80	63.80
	NEWG	77.50	41.30
	NONG	95.00	63.80
9 - 11 [b] N=11	OLDG	52.00	45.00
	NEWG	56.00	65.00
	NONG	84.00	91.70
12 - 14 [c] N=9	OLDG	60.00	62.50
	NEWG	76.00	55.00
	NONG	88.00	90.00
Mean Condition		70.80	64.20
Mean OLDG		53.60	57.10
Mean NEWG		69.80	53.80
Mean NONG		89.00	81.80

(Notes to Table 18)

a
- For the 5 - 7 year olds the mean total trials for the Structured conditions was 30.30. There were 8 'most' subjects who required 35 or more trials to complete the reproduction task, and there were 8 'least' subjects who required 25 or less trials to complete the task.

b
- For the 9 - 11 year olds the mean total trials for the Structured conditions was 21.50. There were 6 'most' subjects who required 26 or more trials to complete the reproduction task, and there were 5 'least' subjects who required 18 or less trials to complete the task.

c
- For the 12 - 14 year olds the mean total trials for the Structured conditions was 18.80. There were 4 'most' subjects who required 21 or more trials to complete the reproduction task, and there were 5 'least' subjects who required 16 or less trials to complete the task.

(1) The Least Group scored lower on the OLDG and performed significanly higher on the NEWG and NONG sequences.

(2) Although the level of performance between the groups on the NEWG and NONG sequence were significantly different, a within comparison, within each group, between the NEWG and NONG scores indicates that for both groups there is an effect of abstracting the underlying grammar, that is, the NEWG scores were significantly lower than the NONG scores.

(3) If we compute the 'comparison score' (2NEWG - 10, see p. 102) for each of the subjects in the Most and Least groups than the mean comparison score for the Least Group (5.5) indicates a very low level of abstraction and the mean comparison score for the Most Group (-1.75) indicates a much higher level of abstraction.

The results of the analysis of this sample are very suggestive, but due to the relatively small size of the sample it is premature to draw any definite conclusions about the relationship between the performance in the acquisition task and implicit processing. On the other hand, the significant differences in recognition between the Most and Least subjects found in the youngest age group have implications for future research. Whenever implicit processing research is planned, if large variances in the subjects' performance of the learning tasks are likely than this factor must be taken into account in the experimental design. In addition, the underlying source of the difference in performance should be explored so that its relationship to implicit processing can be studied.

D. <u>The materials manipulation</u>

The results of changing the stimulus materials used for generating the exemplars (sequences) were in the predicted direction but were not as strong as expected.

The most fundamental requirement for implicit processing is that the subject be actively attending to the learning set. There are, of course, many aspects to the exemplars that can capture the subjects' limited attention and additional aspects that can be automatically attended to. Yet, it stands to reason, that even with the addition of automatic attentional processes (such as those suggested by Hasher & Zacks, 1979) there is a certain limit or selection from the infinite richness of the stimulus environment. In other words, different subjects will sample different aspects of the stimulus material and the more salient (without going into a precise definition of salient) aspects will be more likly to be sampled by a greater number of subjects.

The question is how salient was our stimulus manipulation. The 'simple' stimuli were four simple geometric shapes, each shape in a different color. The 'meaningful' stimuli were four 'meaningful' geometric shapes each shape in a different color. Both the simple and the meaningful stimuli were of the <u>same</u> colors. Therefore, one very salient aspect of the stimuli were identical and it is possible that this fact contributed to the weakening of the effect of the material manipulation. Observation of the childrens' performance in the acquistion phase of the experiment indicates that many of the children were using color as a basis for their learning. This interpertation is reinforced by the subjects' answers to the post-experimental questions which asked them how they went about memorizing or reproducing the sequences. Additional research designed so that color is not a salient aspect of the stimulus material is necessary in order to test the hypothesis more precisely.

E. Multiple types and roles for implicit processing

The raison d'etre of the present reserach - to produce evidence of the existence of implicit abstraction processes in children and to demonstrate that these processes can be studied experimentally - was certainly achieved. The findings confirm the basic predictions and encourage future pursuit of new research which will expand and deepen our understanding of implicit processes and their role in knowledge acquisition.

One interesting direction is suggested by Hasher & Zacks's (1979) distinction between two types of automatic processes: innate, prewired processes and learned or practiced processes. According to their model of automatic processes in attention, the hereditary automatic processes are widely shared by all humans and should show few developmental changes, whereas, the learned automatic processes are created through experience and development and should exhibit substantial developmental differences. If we transpose Hasher & Zacks's model of attention to a model of knowledge acquisition then it is quite possible that in the present research only the innate implicit processes were manifested. Consequently, there were no significant age differences or age effects. Yet, it is quite likely that there are additional implicit processes which are nonhereditary or are built up from initial hereditary processes by learning and development. The present research tested the effect of a single learning event. It may be that in order to find out more about developmental aspects of implicit processes new approaches and methodologies should be explored.

There are two types of research that could be instrumental in achieving this purpose: (1) longitudinal experiments in which learning takes place over time through repeated interaction with complexly structured material; (2) change of experimental methodology so that the tasks are more complicated (not simple memorization), more in the direction of problem solving tasks.

Regardless of what change would be made in the experimental methodology and design, adherence to the basic requisites for implicit learning research must be observed. That is, the underlying structure of the material must be complex in the sense that explicit analytical processes would be inadequate for discovering the rule system. In addition, the tasks for testing the activation of implicit processes must be sensitive to the existence of acquired knowledge of the underlying structure, without requiring the subject to explicate or verbalize this knowledge.

Until such research is carried out, one can only conjecture as to the existence and nature of the 'learned' implicit processes. At this point, it can be tentatively suggested that some implicit processes do indeed go through developmental changes though more primitive forms of processes continue to coexist. The source of the developmental transformation in the implicit processes may be the restructuring of general intelligence as Fischbein (1982), Naus & Halasz (1979) and Nelson & Nelson (1978) postulate, as well as extensive and highly specific practice as Hasher & Zacks (1979) suggest.

In other words, the newborn infant has a set of implicit processes preattuned to the enviornment so that he can pick up regularities and patterns from the environment which are meaningful (in the most general and abstract way) to the human condition and survival (Hasher & Zacks' prewired automatic processes of time, frequency and location are an example of such processes.). These innate processes continue to exist in our repertoire of information processing throughout the life span.

Learned implicit processes are an addition to these prewired processes. Learned processes are built up, on one hand, through experience with the environment, and on the other hand, through the restructuring of general intelligence. They remain nonintentional, unconscious, and automatic. The information that they process has a global, compact, nonanalytical, nonverbalizable, tacit form, but the type of regularities and patterns that they select and can deal with, as well as the complexity and meaning of this information to the subject changes with the person's development and experience.

The transformations these processes undergo is a function of the increment in the knowledge base as well as the cognitive level that the person has achieved. The youngest child is a novice in all system knowledge. He must be able to distinguish between broad differences that will enable him to classify information into different categories rather than build up a particular domain. Whereas the older child has already mastered some systems and demarcated others, the information that he is processing, at this age, is needed for building within the domains. Consequently, in the early stages of development information is important for distinguishing between systems (categories, domains). At later stages in development information serves to build coherence and structure within a system. The nature of implicit processes available to the child should reflect these differences in function.

These speculations about the develoment of different types of implicit processes and resulting tacit knowledge systems suggest the need for further developmental investigations that can distinguish between them.

APPENDIX A

Senior adults - Experiment 1

There were only 3 subjects in this group so they were not included in the statistical analysis. A comparison of the senior adults' average scores with the rest of the sample shows that: (1) the senior adult subjects took a little longer than the adult group to learn the fifteen sequences in Part I (senior adult - 22.1 trials, adult - 19.29 trials); (2) as in all other age groups, the relationship between the NEWG and the NONG instances was NONG2>NONG1>NEWG; (3) the senior adults average correct recognition score for the OLDG (56.25%) was lower than the other three groups; (4) their NEWG (45.7%) scores were higher than the adults and lower than the children; and (5) their NONG1 (68.57%) and NONG2 (87.50%) scores were about the same as the other age groups. (see Table 2 for comparisons).

APPENDIX B

Post-experimental response of subject who understood the explicit instructions

Subject # 83 (14;10, boy)

E: Do you think that the were any rules to this game?

S: Not really, there wasn't any real pattern, they went by. I used a pattern.

E: What was it?

S: Either triangle or diamond came first and most of the time the circle was behind the box. That is how I judged if I saw them or not.

(the pattern the subject used was incomplete but correct).

APPENDIX C

STATISTICAL ANALYSES

Table 19

Split plot ANOVA for percent

of correct recognition

Experiment 1

N=27

SOURCE	SS	df	MS	F	p
Between Subjects	9115.84	24	379.83		
A (Age)	285.16	2	142.58	0.87	0.70
Within Subjects*		22			
B (type of sequence)*		3		93.61*	0.0001**
Interaction		46			
A x B *		6		1.28*	0.28

* Alternative mutlivariate test (due to non-compound symmetry) - Rao's R (R distributed as exact F).

** $p<0.01$

Planned comparisons:

NEWG vs. NONG1 - $F(1,24) = 28.02$, $p<0.01$

NONG1 vs. NONG2 - $F(1,24) = 11.62$, $p<0.01$

OLDG vs. NEWG - $F(1,24) = 16.85$, $p<0.01$

Table 20

Three way ANOVA for total number of

trials to reproduce sequences correctly

Experiment 2

N=117

SOURCE	SS	df	MS	F	p
Between Subjects	3099.83	93	33.33		
A (Condition)	161.49	3	53.83	1.61	0.16
B (Age)	3465.59	2	1732.80	51.99	0.0001**
C (Sex)	0.84	1	0.84	0.03	0.85
Interaction					
A x B	128.55	6	21.42	0.64	0.67
A x C	118.17	3	39.39	1.18	0.32
B x C	6.58	2	3.29	0.10	0.90
A x B x C	187.84	6	31.31	0.93	0.47
Total	78,374.00	116			

** $p<0.01$

Table 21

Three way ANOVA for total time to

reproduce sequences correctly

Experiment 2

N=117

SOURCE	SS	df	MS	F	p
Between Subjects	2120.40	93	22.80		
A (Condition)	343.52	3	114.51	5.02	0.003**
B (Age)	3674.02	2	1837.01	80.57	0.0001**
C (Sex)	4.99	1	4.99	0.22	0.65
Interaction					
A x B	296.66	6	49.44	2.17	0.05*
A x C	117.80	3	39.27	1.72	0.17
B x C	4.16	2	2.08	0.09	0.90
A x B x C	90.20	6	15.03	0.66	0.68
Total	32,096.25	116			

* $p<0.05$ ** $p<0.01$

Planned comparisons:

ImS vs. Imm: $F(1,93)=4.60$, $p<0.03$*

ImS vs. ExS: $F(1,93)=5.34$, $p=0.02$

ImS vs. R: $F(1,93)=0.78$, $p=0.38$

Struc. vs. R: $F(1,93)=8.89$, $p<0.01$

5-7 vs. 9-11: $F(1,93)=82.62$, $p<0.01$

9-11 vs. 12-14: $F(1,93)=8.31$, $p<0.01$

Table 22

Three way ANOVA for rate of

reproducing sequences correctly

Experiment 2

N=117

SOURCE	SS	df	MS	F	p
Between Subjects	13.08	93	0.14		
A (Condition)	2.06	3	0.69	4.88	0.01**
B (Age)	10.33	2	5.16	36.69	0.0001**
C (Sex)	0.01	1	0.01	0.08	0.76
Interaction					
A x B	0.74	6	0.12	0.87	0.57
A x C	0.76	3	0.25	1.74	0.15
B x C	0.26	2	0.13	0.92	0.40
A x B x C	1.03	6	0.17	1.22	0.30
Total	436.34	116			

* $p<0.05$ ** $p<0.01$

Planned comparisons:

ImS vs. Imm: $F(1,93)=0.05$, $p=0.31$

ImS vs. ExS: $F(1,93)=3.97$, $p=0.05$*

ImS vs. R: $F(1,93)=3.63$, $p=0.056$

Struc. vs. R: $F(1,93)=10.71$ $p<0.01$

5-7 vs. 9-11: $F(1,93)=26.98$, $p<0.01$

9-11 vs. 12-14: $F(1,93)=9.89$, $p<0.01$

Table 23

Three way ANOVA for total correct

recognition - Experiment 2

N=115

SOURCE	SS	df	MS	F	p
Between Subjects	933.87	91	10.26		
A (Condition)	143.42	3	47.81	4.66	0.005**
B (Age)	54.78	2	27.39	2.67	0.07
C (Sex)	0.66	1	0.66	0.70	0.50
Interaction					
A x B	32.65	6	5.44	0.53	0.79
A x C	26.33	3	8.78	0.86	0.47
B x C	8.38	2	4.19	0.41	0.67
A x B x C	81.23	6	13.54	1.32	0.26
Total	47,130.00	116			

* $p<0.05$ ** $p<0.01$

Planned comparisons:

ImS vs. Imm: $F(1,93)=2.26$, $p=0.13$

ImS vs. ExS: $F(1,93)=0.04$, $p=0.83$

ImS vs. R: $F(1,93)=5.09$, $p=0.02$*

Struc. vs. R: $F(1,93)=10.64$, $p<0.01$**

Table 24

Split plot ANOVA for percent of correct recognition for the three types of sequences Experiment 2 (N=115)

SOURCE	SS	df	MS	F	p
Between Subjects	328.49	91	3.16		
A (Condition)	42.19	3	14.06	3.90	0.01**
B (Age)	20.65	2	10.33	2.86	0.06
C (Sex)	0.01	1	0.01	0.004	0.91
Within Subjects					
D (type of Seq.)(1)		2		86.61(1)	0.0001**
Interaction					
A x B	10.70	6	1.78	0.49	0.81
A x C	2.84	3	0.95	0.26	0.85
A x D(1)		6		14.35(1)	0.0001**
B x C	11.76	2	5.88	1.63	0.20
B x D(1)		4		1.04(1)	0.40
C x D(1)		2		1.37(1)	0.26
A x B x C	51.72	6	8.62	2.39	0.03*
A x B x D(1)		12		0.24(1)	0.99
A x C x D(1)		6		0.31(1)	0.93
B x C x D(1)		4		0.61(1)	0.66
A x B x C x D(1)		12		1.38(1)	0.18

* $p<0.05$ ** $p<0.01$

(1) Alternative mutlivariate test (due to non-compound symmetry) - Rao's R (R distributed as exact F).

Table 25

Split plot ANOVA for confidence scores

for the three types of sequences

Experiment 2 (N=115)

SOURCE	SS	df	MS	F	p
Between Subjects	40587.35	91	446.01		
A (Condition)	3456.25	3	1152.08	2.58	0.05*
B (Age)	413.66	2	206.83	0.46	0.64
C (Sex)	52.60	1	52.60	0.12	0.73
Within Subjects					
D (type of Seq.)(1)		2		6.11(1)	0.004**
Interaction					
A x B	4776.47	6	796.08	1.78	0.11
A x C	1705.33	3	568.45	1.27	0.29
A x D(1)		6		3.76(1)	0.002**
B x C	5507.52	2	2753.76	6.17	0.003**
B x D(1)		4		0.48(1)	0.75
C x D(1)		2		0.92(1)	0.40
A x B x C	1799.41	6	299.90	0.67	0.67
A x B x D(1)		12		1.62(1)	0.09
A x C x D(1)		6		0.90(1)	0.50
B x C x D(1)		4		0.43(1)	0.78
A x B x C x D(1)		12		0.60(1)	0.84

* $p<0.05$ ** $p<0.01$

(1) Alternative mutlivariate test (due to non-compound symmetry) - Rao's R (R distributed as exact F).

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