SPONTANEOUS ELABORATION OF PAIRED ASSOCIATES AND FORMAL OPERATIONAL THINKING: A DEVELOPMENTAL ANALYSIS

by

RUTH NANCY ELIZABETH GREER

B.A., Carleton University, 1973

M.A., University of British Columbia, 1975

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Department of Educational Psychology

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date June 28, 1977

Abstract

The learning of paired associates has been conceptualized (Rohwer, 1973) as the creation of shared meaning for items that are initially disparate by generation of a common event or episode in which the two referents interact. While children of primary school age have been found capable of applying these mental operations when prompted to do so, their spontaneous use has not been found before adolescence, and then only with considerable variability within any one age group. Spontaneous elaboration was characterized as the habitual adoption of an active, planful, strategy-like orientation to the problem posed by later recall. The intent of this research was to examine the degree to which the presence of the hypothetico-deductive and propositional thinking abilities of the Piagetian formal operational period underlie the propensity to spontaneously elaborate. In addition, the structure of the paired associate list allowed for investigation of the developmental course of spontaneous elaboration across levels of noun abstractness and associative meaningfulness.

The performance of 277 students in grades 6, 8, 10, and 12 was assessed using the Formal Operations Instrument, a paper and pencil, group administered test developed specifically for this purpose. Items included three conservation tasks (weight, volume, density), combinatorial thinking (Piaget's colorless chemicals task) and two of Peel's (1971) verbal problems of propositional logic. Six subjects of each sex within

each grade were then assigned to one of three memory treatment groups: 1) control, given instructions simply to pay attention and do their best to learn the pairs; 2) repetition, instructed to repeat all pairs during study trials; 3) trained, given instructions and practice in generation of both interactive images and meaningful sentences as methods of elaboration. All subjects were required to learn a mixed list of eight concrete and eight abstract noun pairs over three repeated study and test trials. Within each concreteness level, one half of the pairs were of high associative meaningfulness (m) while the other was of low m.

Recall results indicated spontaneous use of elaboration for both concrete and abstract pairs by the tenth grade level from the onset of trial 1. There was some evidence of spontaneous elaboration of concrete pairs at the sixth grade level, but not until the third trial. These results did not interact with level of m. Prompted use of elaboration was evident from the performance of the trained groups at all grade levels and with all pairs with one exception, grade 6 students with low m abstract pairs. It was inferred that some minimal level of richness of associative possibilities must be present in the materials for a given child if a semantic coupling is to be created.

A modest relationship between formal operational abilities and overall recall performance was found. There was no evidence to support the contention that these abilities are uniquely related to that aspect of performance responsible for spontaneous evocation of elaborative processes, however. Lack of specificity in the processes involved in performance on both the Piagetian and the memory task, as well as difficulties in

assessment of formal operational abilities were felt to be primarily responsible for this lack of aptitude-treatment interactions. Implications of this research for the timing of content and of instruction in processing skills within the classroom were discussed.

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CHAPTER I

Introduction

It has been well documented (Paivio, 1971) that when the normal adult is placed in an intentional memory situation, it is the rule rather than the exception that a variety of coding strategies are brought into play which transform items. The mature learner spontaneously organizes, rehearses, elaborates, and generally becomes engaged in an "effort after meaning" (Bartlett, 1932, p. 227) in an attempt to ensure subsequent recall. The young child, by contrast, tends to respond passively as stimuli for later recall are being presented, failing to deploy even the most rudimentary forms of selective attention (Appel, Cooper, McCarrell, Sims-Knight, Yussen, & Flavell, 1972; Druker & Hagen, 1969; Haith, 1971). As a child proceeds through the school years he has been found to become more proficient in tasks requiring memory. For example, among the strategies which have been documented to increase in spontaneous use with age are tactical rehearsal during serial recall (Belmont & Butterfield, 1971; Brown, 1975; Butterfield, Wambold, & Belmont, 1973; Flavell, Beach, & Chinsky, 1966; Flavell, Fredrichs, & Hoyt, 1970; Hagen, 1972; Kail, 1976; Kellas, McCauley, & McFarland, 1975), imposition of organization through clustering in free recall (Bjorklund, Ornstein, & Haig, 1975; Moely, 1969; Neimark, 1971; Worden, 1975), and generation of a common referential event between pair members in paired associate learning (Kemler & Jusczyk, 1975; Klemt & Anderson, 1973; Paivio, 1971; Pressley, 1976; Rohwer, & Bean, 1973),

Mediation Versus Production Deficit

It has been suggested (Kendler, 1963; Reese, 1962) that the low performance of the young child in the memory situation was due to a mediational deficit. That is, while the appropriate mediator might be generated by

the child, it failed to serve as a mediator for anything during recall. Considerable evidence exists to demonstrate that such is not the case. Given a mediational event or brief instructions in the appropriate mediational strategies which orient the individual to process information semantically, four and five year old normal children (Brown, 1975; Corsini, Pick & Flavell, 1968; Levin, McCabe & Bender, 1974; Moely, et al, 1969; Murphy & Brown, 1975; Yuille & Catchpole, 1974) and mentally retarded children (Turnure, Buium & Thurlow, 1975) will utilize and generate mnemonic strategies to facilitate recall.

An alternative to the mediational deficiency hypothesis has been proposed by Flavell and his associates (Flavell, et al, 1966). According to the production deficiency hypothesis, the young child simply fails to recognize the need for, nor spontaneously produces potential mediators. This point is well illustrated by the fact that young children will successfully employ a mediational strategy when instructed to do so, but will abandon it when no longer explicitly required to use it by the experimenter (Flavell, 1970). This production deficit has been further elaborated by Flavell (1970) as involving what he referred to as a "general" and a "specific" aspect (p. 205). The "specific" refers to the acquisition and refinement of particular cognitive activities or operations which underly the use of a variety of mnemonic strategies. The "general" aspect refers to increasing awareness, and propensity on the part of the child to engage in 'planning activities' during encoding in anticipation of later recall, activities which Flavell suggests can be viewed as a kind of "cognitive executive routine" (p. 205).

This latter aspect of memory development has more recently been subsumed under the general category of "metamemory", which is conceptualized

as "...the individual's knowledge of and awareness of memory, or of anything pertinent to information storage and retrieval." (Flavell & Wellman, 1976, p. 4). In addition to serving the executive function refered to above in eliciting the planning and coordination required of spontaneous application of mnemonic strategies, it should be noted that metamemory development includes additional competencies. For example, sensitivity to different memory task requirements, discrimination of relevant from irrelevant stimulus attributes as they influence memory, awareness of memory span limitations both in time and capacity, as well as selection of appropriate record-keeping, search, and other retrieval strategies are all conceptualized by Flavell and Wellman (1976) to be components of metamemorial development.

Thus, some form of internal cueing which spontaneously activates the 'planning activities' referred to above is conceptualized as resulting from the development of a metamemory "executive routine". The mnemonic training literature with young children (cf. Brown, 1975; Hagen, 1973; McCabe, Levin, Wolff, 1973; Rohwer, 1973; Yuille & Catchpole, 1973) has made it apparent that externally provided prompts can serve the function that this internal cueing performs. It is the development of the processes of this executive control system of metamemory however, which is conceptualized as providing the capabilities for the spontaneous and adaptive mnemonic activities that distinguish the mature memorizer from the young child.

The preceding attention to the executive control system is not intended to devalue the importance of the development of the cognitive operations required for specific mnemonic strategies. Any potential memory outcome must more accurately be seen as reflecting an interrelationship of three factors: the situation or task characteristics, the behaviors or 'specific'

operations available in the repertoire, and the child's awareness or his/her 'metamemory' (Flavell & Wellman, 1976).

Elaboration in Paired Associate Learning

The paired associate paradigm has been used extensively by Rohwer (see 1973 for review) as a vehicle for examining developmental changes in memory. Rohwer (1970, 1973, 1977) has proposed that the coupling that occurs in this task is brought about by a process that creates a shared meaning for the items. The assumption here is that what is stored in memory concerning individual items are components of their meaning ("meaning here used to denote abstractions and not words, images or copies of sensory or motor reality" (1973, p. 4)). The content of learning in the paired associate task is regarded as "... the residuum of creating a shared meaning for items that are initially disparate." (p. 4). The process itself is thought to consist of generating a common referent for the items to be coupled, through direct participation in or observation of such an interaction, or through the recombining of existing memories (Rohwer, 1977). When the pair is comprised of unrelated objects or items, the common referent will typically be an 'event' in which the two separate referents interact (1973). One member of the pair can then serve as a cue for the joint referential event itself, and the second member of the pair can be easily retrieved by virtue of being an inseparable part of this shared meaning. Rohwer (1977) has used the term 'elaboration' to refer to these "...mental operations which constuct an event or series of events that incorporate otherwise disparate entities and actions." (p. 1).

The developmental progression in the conditions necessary to activate the elaboration process has been examined in some detail by Rohwer and

others. In this regard, Rohwer (1973) refers to five levels of explicitness of prompt which can be provided by the experimental situation and which can influence the occurance of elaborative processes. The first of these is the antagonistic prompt which directs the learner to engage in repetition, counting, or other activity which will preclude the generation of a common referential event, and thus is taken to represent a baseline condition. The second is the minimal prompt, also refered to as the neutral or control condition. In this situation instructions simply to learn or memorize the material are given. With the explicit prompt instructions are given regarding a process which might be used by the subject while attempting to learn the pairs (i.e., create a story, make up a picture in your mind, etc.). The augmented explicit prompt provides the subject with the referential event (i.e., a picture of two objects interacting, a sentence). The final and most explicit type of prompt is the maximally explicit. In this condition the referential event is enacted directly in the presence of the learner.

With development the explicitness of the prompt necessary to activate elaboration has been found to decrease. Two particular periods of shift have been found. Prior to 5 or 6 years of age no difference has been found between the explicit and the minimal prompt conditions (Jensen & Rohwer, 1965; Rohwer, 1970; Wolff & Levin, 1972). Even though these young children are given instructions concerning the procedures they might use to generate a common referential event, they are unable to do so unless the event is enacted before them. After 7 years of age, however, the explicit prompt has generally been found to result in learning equal to that under augmented explicit and maximally explicit prompts (Yuille & Catchpole, 1973).

Performance under the minimal prompt continues to be no better than that under the antagonistic prompt during the childhood years, however (Rohwer & Bean, 1973; Rohwer & Guy, 1973; Suzuki & Rohwer, 1969).

The next period of noticable change occurs during the adolescent years, a change which Rohwer (1973) has referred to as the development of a 'strategy-like orientation'. It is marked by an increase in performance under minimal prompting equal to that of the more explicit prompt groups (Greer & Suzuki, 1976; Rohwer & Bean, 1973). The implication drawn is that there is an increasingly spontaneous generation of elaborative events with age, the critical period of change from non-production to spontaneous production falling somewhere between the sixth and eleventh grade.

In summary, the performance of the child between the ages of five and fourteen would indicate that the mental operations required to produce an elaborative event are available but are dependent upon external cueing to become activated. The older adolescent will spontaneously cue these mental operations in the absence of specific external prompts to do so such that his performance does not differ from peers given more explicit experimental support. Re-phrased in Flavell's terminology (1970), at approximately the age of five the child developes the 'specific' cognitive operations underlying elaboration but the development of the 'general cognitive executive routine' responsible for the internal cueing of these processes does not emerge in performance until the adolescent period.

Development of Spontaneous Elaboration

Since these initial reports, a number of theoretical issues of concern have been raised with respect to the development of spontaneous elaboration during adolescence. First, attempts to replicate the trend noted by Rohwer

and Bean (1973) have been inconsistent. While Greer and Suzuki (1976) reported success in reproducing the original trend with concrete pairs, repeated attempts by Rohwer and his associates (Rohwer, Raines, Eoff & Wagner, 1977) have generally met with failure.

Second, the results of this more recent research of Rohwer's (1977) plus that reported by Pressley and Levin (1977) have made it apparent that age alone does not adequately account for the variability in elaborative propensity during the adolescent period. In addition, neither I.Q. test scores nor measures of scholastic achievement have served to differentiate producers from non-producers at any one age level, although level of performance on a previous paired associate task does so (Rohwer, et al. 1977).

Third, qualitative differences in the characteristics of noun pairs have been found to influence the degree to which this propensity is manifest in performance. For example, low stimulus term frequency (Klent & Anderson, 1973) has been found to decrease the incidence of spontaneous elaboration in adults, while low pair frequency has been less systematic in its influence on performance of adolescents (Rohwer, et al, 1977). Evidence of a horizontal décalage in age of onset of spontaneous elaboration as a function of pair abstractness has also been reported (Greer & Suzuki, 1976). However, level of abstractness was not completely disentangled from level of associative meaningfulness, making it unclear which variable accounted for this pattern.

Fourth, the validity of the assumption that the repetition group really constitutes a sufficient baseline of performance against which to assess spontaneous elaboration by the minimal prompt group has been questioned (Greer & Suzuki, 1976; Rohwer, et al, 1977). For example, some antagonis-

tically prompted subjects in the Greer and Suzuki study reported use of other mnemonic strategies despite instructions to repeat pairs covertly.

It is apparent from the foregoing that further research is required if both the validity and the nature of the parameters influencing the developmental trend in spontaneous elaboration identified by Rohwer and Bean (1973) are to be established. Five issues have evolved from the previous investigations of this form of memory development which will be addressed by this research. The first three of these concerned primarily the development of the "executive control processes' responsible for the propensity to spontaneously elaborate. The last two issues sought to examine further task variables potentially influential to the application of elaborative processes, when prompted.

First, further verification of this planfulness in a memory task was sought by attempting to replicate the developmental trend during adolescence in spontaneous use of elaboration which had been found by Rohwer and Bean (1973) and Greer and Suzuki (1976) but which had taken on a rather illusive quality in other research (Pressley & Levin, 1977; Rohwer, et al, 1977). In addition, overt rather than covert rehearsal of the pairs during all interitem study intervals was required of the subjects in the antagonistically prompted group in an attempt to further insure inhibition of elaborative processes.

The second issue concerned an exploration of the extent to which cognitive developmental changes during adolescence accounted for the variance in observed elaborative propensity. It was apparent from the existing research that age, I.Q. scores, and measures of scholastic achievement did not satisfactorily account for this variance. From the Piagetian position

(Piaget & Inhelder, 1973) memory should appropriately be viewed as the application of the operational structures of the intelligence to the task of retention and reconstruction of the past. Thus, memory task performance will reflect the developmental status of the cognitive system as a whole. Cognitive developmental changes during the adolescent period appear to be the next logical step in seeking to identify the source of this variance in elaborative propensity. In Rohwer's early discussion of elaboration (1973, p. 8) he makes reference to cognitive developmental changes of a Piagetian form as being implicated in the memory performance of adolescents, but (to the writer's knowledge) this association has as yet not been subjected to a critical empirical test.

Specifically, the present research examined the degree to which the problem solving and propositional thinking skills of the Piagetian formal operational period were responsible for the differences in elaborative propensity during adolescence. These operational changes described by Inhelder and Piaget (1958) as being associated with the formal period appeared to be particularly relevant, given the nature of the competencies which are thought to be associated with the development of "executive control". That is, it is the tendency to approach the memory task in a problem-solving fashion, to perceive the task as one which requires the active generation and testing of multiple elaborative alternatives, and the ability to coordinate multiple mental operations which this executive control allows for, and which separates the spontaneous from the prompted elaborator. The parallel between this type of competency and that of the hypothetico-deductive processing skills of the formal operational period made this a potentially fruitful relationship to investigate.

The third issue concerned clarification of the influence of two task variables, associative meaningfulness (m) and abstractness. Rohwer (1973), in discussing the elaborative process, stated that the creation of a semantic relationship between the two members of a pair is dependent to some extent upon the variety of meanings stored in memory which are associated with each item initially. Klemt and Anderson (1973) and Rohwer, et al (1973) employed frequency counts as an index of richness of associative possibilities. However, a more direct measure of this dimension would be associative meaningfulness. Through the use of nouns for which adolescent m norms have previously been tabulated (Greer and Suzuki, 1976), it was possible to systematically examine the influence of this variable.

Level of abstractness remained a variable of interest in the present investigation of elaboration propensity, given the horizontal décalage observed previously by Greer and Suzuki (1976). Borrowing a concept from the levels of analysis model of memory proposed by Craik and Lockhart (1972), one of the major determinants of depth of processing (and hence of later recall) is assumed to be the degree to which material is compatible with existing cognitive structures. One of the central advances of Piagetian formal operational thinking is the ability to deal with abstract concept as the elements of thinking (Inhelder and Piaget, 1958). Rohwer (1977) has also made reference to the idea that with development elaboration becomes increasingly mental and is less dependent upon the direct interactive form. Abstract noun pairs which are devoid of external referents would appear to rely more heavily upon this more purely mental form of elaboration than would concrete pairs, and may consequently evidence a somewhat different developmental trend in onset of spontaneous elaboration. It

became of theoretical interest to re-examine the abstractness-concretness dimension both by itself and in interaction with cognitive developmental indices. The structure of the paired associate list allowed for this type of examination while simultaneously controlling for m within the two levels of abstractness.

The fourth issue concerned the generalizability of the elaborative prompts given to an individual during training to material of different levels of meaningfulness and concreteness. A body of literature exists to demonstrate that young children of five years and older are capable of performing the specific cognitive operations necessary to elaborate when given explicit prompting to form an interactive image or to embed the noun pair in a meaningful phrase or sentence. This research, however, has concentrated on the demonstration of responsiveness to training and instructions only under the very favorable conditions of highly familiar and meaningful concrete nouns and has not examined performance across a range of item difficulty. In their discussion of developmental stage transitions, Flavell and Wohlwill (1969) have proposed that asynchrony in achievement across levels of task difficulty may be found as operational competency only gradually becomes consolidated in performance. A similar point was made above concerning the elaboration of concrete versus abstract pairs. The appropriateness of this analysis to the elaboration of paired associates was examined in this research by comparing recall levels of trained students over material which represented somewhat of a continuum of item difficulty.

A final issue addressed in this research involved the ability of explicitly prompted preadolescents and adolescents to vary strategies as characteristics of the material to be learned changed. A mature individual

responds to a mixed task with a spontaneous and adaptive change in preparatory activity (Reitman, 1970). It was of interest to determine if children trained in more than one strategy (imaginal and verbal) would respond to the requirements of the mixed list of concrete and abstract paired associaties with both strategies, or would perseverate in the use of only one strategy throughout.

According to Paivio's dual coding hypothesis (1969; 1971), both a visual and a verbal system are available for the encoding and storage of information in memory. The characteristics of the task and the material to be learned can be varied such that one system is more likely to be employed than the other. For example, the following information regarding latency of production of interacting images versus verbal elaborations of concrete and abstract pairs has been documented:

		Concrete Pairs	Abstract Pairs
Grade 6	Imaginal (Yuille & Pritchard, 1969)	9 seconds	12 seconds
	Verbal (Greer & Suzuki, 1976)	10 seconds (?)	10 seconds (?)
Adults	Imaginal (Paivio, 1975)	3 seconds	12 seconds
	Verbal (Paivio, 1975)	3 seconds	3 seconds

The question mark beside the data for grade 6 students for verbal elaboration is to denote the fact that this research (Greer & Suzuki, 1976) was not specifically designed to provide latency information. It did indicate, however, that approximately 60 percent of the sixth grade children trained to embed concrete and abstract pairs within a meaningful sentence reported success in doing so within a 10 second interval. Extrapolating from the

information provided above, students from sixth grade and older, given a mixed list of concrete and abstract pairs, a pace rate of 10 seconds, and training in both imaginal and verbal elaboration strategies should not express any particular preference for one processing mode over the other for concrete pairs. For the abstract pairs, however, it would be predicted that verbal strategies would have a greater probability of leading to successful elaboration, given the 10 second pace rate. In summary then, the dual coding hypothesis would predict equivalent use of the two modes of elaboration for concrete pairs, but preferential use of the verbal mode for abstract pairs.

It should be noted that Rohwer's (1973) elaboration hypothesis is basically amodal, placing the emphasis on variations due to prompt explicitness rather than to modality differences, "...a single-process approach, as exemplified in the elaboration hypothesis, may be more heuristic than a multi-process approach for advancing toward an understanding of the major determinants of learning efficiency in childhood and adolescence" (p. 53). Various modes or prompt types are simply seen as more or less effective in cueing semantic overlap. To date, however, the elaboration hypothesis has been applied to developmental changes in performance with highly concrete objects and/or nouns, a class of stimuli which the dual-coding hypothesis would predict to be equally amenable to verbal and imaginal processing modes. Pattern of reported elaborative strategy usage was felt to be a pertinent question to address in the context of this investigation of elaborative processing as performance was examined with a mixed list. By training subjects in both verbal and imaginal elaborative modes and then examining the reported usage of these strategies in response

to the mixed list, this issue could be examined.

Translating these issues into research questions, the following were examined by the present research:

(1) During later childhood and adolescent period (i.e., grades 6, 8, 10, 12) is there a trend toward increasing use of spontaneous elaboration during paired associate learning?

(2) Does elaborative propensity within any grade level interact with:

a. level of abstractness of pairs to be learned?

b. level of associative meaningfulness (m) within level of abstractness?

(3) If evidence of spontaneous elaboration is found, is there a relationship between formal operational abilities and spontaneous elaboration such that if variance accounted for by the former is statistically removed, the variance by grade in the latter is also removed?

(4) Does training in imaginal and verbal mnemonic strategies improve recall performance over that of a group instructed to use repetition:

a. at all four grade levels?

b. over both high and low levels of abstractness of nouns to be learned?

c. over both high and low levels of associative meaningfulness?

(5) Does frequency of reported use of elaborative and non-elaborative strategies by trained subjects vary as a function of:

a. grade?

b. level of abstractness of nouns to be learned?

c. level of meaningfulness?

CHAPTER II

Literature Review and Theoretical Background

Memory Development:

A wide variety of processes and tasks are subsumed under the general label of memory development research (Reese, 1973). In her examination of this topic, Brown (1975) provided a framework within which to view the various aspects of this research. Within her analysis, memory development can first be seen as the development of "knowing" in general, or of the semantic and conceptual memory which underlies all cognitive activity, a division analogous to what Piaget (Piaget & Inhelder, 1973) have refered to as "memory in the wider sense".

The second category Brown has called "knowing how to know" and refers to the individual's repertoire of mnemonic strategies in the form of cognitive operations which can be applied to transform sensory data at input or assist in later retrieval. The course of the development of this form of operational competence has generally been examined using a training or instructional paradigm. For example, success in training of clustering techniques during free recall has been reported with preschool (Murphy & Brown, 1975) and primary grade children (Bjorklund, Ornstein, & Haig, 1975; Worden, 1975). The assumption in this research is that while the young child may not evoke these strategies of his own accord unless specifically cued to do so, he does have the operational competence required to carry them out.

The third category referred to by Brown was termed "knowing about knowing", or what has more recently been referred to as metamemory (Flavell and Wellman, 1976). It is the development of a type of executive control system

which, among other things, is thought to account for the emergence of spontaneous application of available mnemonics refered to in the preceding paragraph. Evidence of the development of this active and planful approach to tasks requiring memory during the intermediate school years has been found for such strategies as deployment of selective attention (Appel, Cooper, McCarrel, Sims-Knight, Yussen, & Flavell, 1972; Hagen, 1972; Hagen & Hale, 1973), tactical rehearsal (Butterfield, Wambold & Belmont, 1973; Hagen, 1972; Kail, 1976; Kellas, McCauley, & McFarland, 1975) and progressive elaboration (Brown, 1975) during serial recall, and clustering during free recall (Moely, et al, 1969; Neimark, 1971), in addition to the paired associate evidence referred to below.

Flavell (1970; 1971) has referred to this inability of young children to spontaneously generate effective mediational strategies as a production deficiency. One component of the growth away from this state of production deficiency is the development of a general tendency toward planfulness, or a propensity for "...searching the repetoire for activities to perform now, the performance of which has no immediate relevance but will facilitate some other activity subsequently" (Flavell, 1970, p. 40). It should be stressed that in addition to the development of this type of executive control is also the complementary development and refinement of the cognitive operations which underly the mnemonic activities required for effective performance in various recall tasks.

It is to be expected that there will be periods of production inefficiency, the transition from non-producer to producer being conceptualized as a gradual rather than an all-or-none process (Flavell, 1970). For example, rehearsal errors during serial tasks (Kellas, McCauley, & McFarland,

1975), incomplete clustering during free recall (Bjorklund, Ornstein, & Haig, 1975), and generation of sub-optimal mediators during paired associate learning (Jensen & Rohwer, 1965) could all be viewed as examples of production inefficiency.

In addition to periods of production inefficiency, one might also anticipate some form of horizontal décalages in performance for a given individual. That is, intraindividual differences may be noted across materials of differing levels of familiarity or meaningfulness as the cognitive operations underlying the mnemonic acquired increasing scope of generality and applicability. Flavell and Wohlwill (1969) have refered to this type of 'operations by materials' interaction. In their analysis, the probability that cognitive competency will be fully expressed in performance will be a joint consequence of the degree to which the necessary operations are fully established and the degree to which the attributes of the task themselves (i.e. manner of presentation; number of irrelevant variables; familiarity of materials; etc) allow for optimal performance.

Giving this concept the mathematical interpretation proposed by Pascual-Leone (1969), performance in tasks requiring the same logical structures will differ within any one child (1) if the information processing demands (as determined by the number of figurative and operative schemes which must be coordinated simultaneously) differ, and (2) if this number exceeds the maximum processing space available to the child for one task but not for the other. For example, Prawat and Concelli (1976) examined the use of constructive memory in seven-year-olds. This paradigm examines the tendency of the individual to falsely recognize as familiar correct logical inferences which are implied in the meaning but not explicitly

stated in a series of statements. Some competence with this inferential memory activity was found when three statements were used. If four or five original statements had been used, however, it is possible that this increased processing demand would result in failure for children of this age whose maximum processing space is three schemes (Case, 1970). Thus, although the logical competence would be within the repetoire, the characteristics of the task itself would result in failure-like performance.

In summary, memory development from the production deficit approach could be chacterized as the development of the ability to use and the spontaneous use of a variety of mnemonic routines across a variety of task characteristics.

Memory Development In Paired Associate Learning:

Examples of this transition from non-production to production of effective memorial strategies in the paired associate task have been reported in the research literature. Rohwer (1973) has proposed that the learning of a paired associate be conceptualized as the generation of a shared meaning or semantic coupling between two initially disparate items. The assumption here is that what is stored in memory for each individual item are components of meaning in a form analogous to conceptual attributes. The process of elaboration itself is thought to consist of generating a common referent for the items to be coupled by recombining existing memories (either by direct involvement or observation of the enactment of an interaction, or in a purely mental form) or through the generation of some 'event' or 'episode' in which the two separate referents interact (Rohwer, 1973). One member of the pair can then serve as a retrieval cue for the joint referential event. The second member can be then easily retrieved by

virtue of being an inseparable part of this shared meaning.

Research evidence indicates that with age there is a decrease in the explicitness of the prompt required to initiate this semantic processing (Rohwer, 1973). It has been repeatedly demonstrated that very young children are able to use experimenter provided elaborations of both the verbal and imaginal form (e.g. Holyoak, Hogeterp, & Yuille, 1972; Rohwer, 1967; 1970; 1973), suggesting that a mediational deficit (Reese, 1962) is not the problem. Evidence of a production deficit in both the tendency to spontaneously produce elaborative events, and in the operational capability to do so during the pre-school and early school years has been documented.

Dealing first with the operational competency involved in elaboration of paired associates, there is some inconsistency in the literature concerning the operational capabilities of children in the four to six year range to respond to prompts to generate either imaginal elaboration in the form of interacting images or verbal elaboration by embedding the pair in a meaningful phrase or sentence. Yuille and Catchpole (1973) report children as young as five years of age can benefit from instructions to generate interacting imagery to the extent that performance is equivalent to groups having experimenter provided interactions. Others (Montague, 1970; Rohwer & Eoff, 1973; Wolff & Levin, 1973) have failed to find any benefit of this form of instruction for children of this age. By age seven a facilitating effect equivalent to experimenter provided imaginal interactions are generally reported (Kemler & Jusczyk, 1975; Levin, Davidson, Wolff, & Citron, 1973; Rohwer & Eoff, 1973; Wolff & Levin, 1972). However, addition of manipulation of the object pairs has been found to facilitate the specific production deficit in the four and five year olds in some studies (McCabe,

Levin, & Wolff, 1973; Wolff & Levin, 1972; Wolff, Levin & Longobardi, 1972) but not in others (Levin, McCabe & Bender, 1974; Yuille & Catchpole, 1973). Rohwer (1977) has observed that "In the course of development, there is a change in the balance between elaboration through interaction and purely mental elaboration, in that the early dominance of the interactive form gives way more and more to the mental form". (p. 10). For some five and six year olds at least, a semantic coupling did not obtain without the opportunity to directly enact the interaction.

There is also evidence that ability to respond to prompts to generate interacting images continues to be refined during the later school years. For example, Yuille and Pritchard (1967) found that both latency of imagery production and number of images successfully generated increased from grade 2 to grade 6. Begg and Anderson (1976) also report that ability to use this form of elaboration increased from grade 2 to grade 6. While trained children at both grade levels exceeded performance of untrained peers, grade 6 trained children also exceeded grade 2 trained children.

Examination of the abilities of children in the four to seven age range to carry out the specific operations involved in the generation of verbal elaborators in response to instructions have been similarly inconclusive. While some research has found children in this age range improve their recall performance when given instructions to elaborate verbally (Kemler & Jusczyk, 1975; Levin, Davidson, Wolff & Citron, 1973; Levin, McCabe & Bender, 1974; McCabe, Levin & Wolff, 1973), others have not found this to be the case (Buium & Turnure, in press; Jensen & Rohwer, 1965; Martin, 1967; Rohwer, 1970; Turnure, Buium, & Thurlow, 1975). It would seem that the difficulty of children in this age range is better characterized

as one of production inefficiency rather than as production deficient in abilities to employ this form of elaboration, however. As reports of Jensen and Rohwer (1965) show, children of this age produce "sentence fragments" or "conjunctives" when told to generate a sentence, which do not function as effective referential events denoting shared meaning. Recent research by Turnure and his associates (Buium & Turnure, in press; Turnure & Buium, 1975; Turnure, Buium, & Thurlow, 1975) has examined the use of interrogatives as prompts for verbal elaboration in both normal pre-schoolers and mentally retarded children. When these children are prompted by "why" and "what" questions concerning the noun pairs recall consistently exceeds both 'sentence generate' and 'sentence provided' groups. In addition, errors made by children prompted interrogatively tend to be predominantly semantic as opposed to non-semantic, suggesting that children of this age level are capable of performing the cognitive operations involved in elaborative processing at the semantic level if given appropriate prompts.

In summary, this research concerned with the operational capabilities involved in "knowing how to know" indicates production inefficiency during the early school years in response to both imaginal and verbal elaborative prompts, with increasing efficiency in the generation of referential events through the middle school years. There is also evidence to suggest that these specific abilities involved in elaboration continue to be refined and to achieve broader fields of generalization during later adolescence. For example, grade 6 students have been found capable of elaboration of concrete nouns when prompted to do so but a considerable number were not able to elaborate abstract pairs, unlike students in grades 8 and 10 (Greer and Suzuki, 1976).

The development of the 'general' metamemory component as evidenced by spontaneous unprompted elaboration has also been examined. The accumulated research indicates lack of spontaneous elaboration to either the verbal (Kemler & Jusczyk, 1975; Pressley & Levin, 1977; Peterson, 1974; Rohwer & Bean, 1973; Rohwer, Raines, Eoff, & Wagner, 1977) or imaginal prompts (Begg & Anderson, 1976; Clarkson, Haggith, Tierney, & Kobasigawa, 1973; Greer & Suzuki, 1976; Levin & Kaplan, 1972; Rohwer & Eoff, 1973) prior to the eighth grade level. The propensity to spontaneously elaborate when given no specific instructions with regard to strategy was first examined by Rohwer and Bean (1973). Children from grades 1, 3, 6, 8, and 11 were given a 36-item paired associate list of concrete nouns. The performance of four experimental groups were examined: an antagonistic prompt group was instructed to repeat each pair; a minimal prompt group was simply told to try their best to learn the pairs; an explicit prompt group was instructed to form and utter aloud sentences containing the pairs; and an augmented explicit prompt group was provided with a sentence which contained the pairs. The results indicated that the effect of minimal prompting relative to either of the sentence conditions or the repetition condition changed sharply with age. At the first, third, and sixth grade levels, the effect of minimal prompting was indistinguishable from that of the antagonistic prompt; at the 11th grade level it was equivalent to explicit and augmented explicit prompt conditions and at the eighth grade level, its effect was midway between these two extremes. The implication drawn was that there is increasingly spontaneous generation of elaboration with age, the critical period of change from non-production to production falling somewhere between the sixth and eleventh grade.

Since this original research attempts to replicate this developmental trend have been mixed and have varied with changes in the characteristics of the material to be learned. For example, Klemt and Anderson (1973) report lack of spontaneous elaboration among adults in response to low frequency nouns, the explanation being that nouns low in frequency are less rich in associative possibilities. Similarly, associative meaningfulness and level of abstractness have been found to influence age of onset of spontaneous elaboration (Greer & Suzuki, 1976). While evidence of spontaneous elaboration with highly meaningful concrete nouns was found at the eighth grade level in this study, such performance was only beginning to emerge with abstract nouns of lower levels of meaningfulness at the tenth grade level.

In summary, productive memory development in response to the paired associate task can be seen as advancing along two fronts. One of these is the acquisition of elaborative processes which can be applied with increasingly greater proficiency and generality. The second, emerging somewhat later developmentally is the growing propensity to approach the task of memorizing in a planful, problem-solving-like manner, and to spontaneously call into play one's storehouse of elaborative processes. The essence of this development of productive memory has been appropriately summarized by Hagen (1971):

> What he is really learning is that he himself determines how well he does, and that he can improve his performance if he uses certain of his new skills in certain task situations. Thus, the intention to remember comes about because the child has learned that remembering is both possible and desirable. He also has

> learned that his ever increasing (cognitive) skills can be put to use in a memory situation. The employment of these skills in task-appropriate strategies during the acquisition phase of a memory task results in enhanced memory performance, and he is further encouraged to use the strategies as well as to develop even more efficient ones. (p. 268)

Memory Development as Cognitive Development:

In Rohwer's (1973) original statement of the elaboration hypothesis the major emphasis was on the characteristics of the prompts which were necessary to serve as catalysts for the elaboration process. This research led to the general conclusion that explicitness of the required prompt decreased with age to the point where no specific prompt other than to remember was required during later adolescence, as demonstrated by the Rohwer and Bean (1973) research. From this body of research, Rohwer (1977) has more recently gone on to make the statement that "... intellectual development consists of increasingly independent elaborative activity".

Further attempts to replicate the adolescent developmental trend have served to emphasize the fact that elaborative propensity shows considerable variability within any one age level and is far from a universal skill. The source of this variance remains an open issue. In his earlier discussion of elaboration, Rohwer (1973) implied that cognitive developmental changes of a Piagetian form may underlie the changes in elaborative propensity: "...developmental changes in conceptual processes during the period of adolescence permit the operation of elaboration in the absence of concrete external prompts." (p. 8) and references Inhelder and Piaget (1958) in this regard. A brief consideration of the Piagetian position concerning

the relationship between the development of memory and that of general intellectual functioning is called for if the implications of Rohwer's suggestion are to become apparent.

Piaget and Memory: The Piagetian position (1969) repeatedly stresses that memory of an event is more than a passive and receptive record of what is perceived, a position also held by the elaboration model; "...the present formulation disavows any notion that the contents of memory are words, pictures, or any other kind of copy of sensory or motor reality" (Rohwer, 1973, p. 4). Rather memory, according to the Piagetian position, is closely bound up with the level of understanding which is brought to the task and as such is best seen as one special case of intellectual activity applied to the reconstruction of the past. A distinction is made by Piaget between what is commonly called memory on the one hand, and the conservation of the schemes of the intelligence on the other. "Memory in the wider sense" is that which involves the conservation of the general schemes in the form of repeatable processes and operations, while "memory in the strict sense" involves the recognition, reconstruction and recall of singular situations, events, or objects which have been personally experienced and are localized in the past. The emphasis on personal experience is also reflected in the elaboration model: "In an elaborative conception, learning is seen as the mental construction of events, or event sequences (episodes), that serve to relate the otherwise isolated entities and actions that comprise them. Such events invariably have personal reference, whether it is implicit or explicit" ... "personal reference is omnipresent in learning." (Rohwer, 1977, p. 8).

This "memory in the strict sense", in the Piagetian view is a store

of information in figurative form that has been encoded through perceptive and conceptual assimilation as a result of the transformations of input brought about by the operational structures (memory in the wider sense) which are available to the child. Thus any specific information which is not 'an object of knowing' or understandable to the child (as determined by the operational sructures available) cannot be recalled because it cannot be assimilated to any scheme presently in the repertoire. The code which retains these 'memories in the strict sense' is initially conceived of as not highly structured and as involving few rules or schemes in the preoperational child, being mainly directed toward accommodation and the figural extension of the schemata. With age the level of memory organization will change to reflect the operational development of the child. A specific event is retained by virtue of it being initially assimilated to one or more operational schemes, and is represented in the form of any accommodatory adjustments in these schemes which may result. Recall will be brought about by a reconstructive process of reintegration of these schemes which carry the results of this accommodatory activity. Thus, with age the code will acquire greater schematization as the child can employ and coordinate more elaborate operations. The goal of this greater schematization is to eliminate redundancies as much as possible and allow for the retention of the maximum number of data with the minimum amount of information.

The relationship between the operational schemes and changes in the nature of the code which holds information available for later reconstruction has been the principle thrust of the Piagetian research. The work of the Genevan group itself (Piaget & Inhelder, 1973) along with that of

several others (Altemeyer, Fulton & Berney, 1969; Furth, Ross, & Youniss, 1974; Liben, 1974; 1976) have been concerned principally with demonstrating spontaneous changes in memory code over periods ranging from one week to one year, accounting for this change in the figurative aspect by operative growth which led to a revision of the "old" code. A small number of empirical investigations of the relationship between development as defined by Piaget and memory performance in traditional laboratory tasks are available. For example, Tomlinson-Keasey, Crawford, and Miser (1975) report finding a significant relationship between clustering during free recall and Piagetian class inclusion and hierarchical classification skills in kindergarten and first grade children. The inference drawn was that classification skills are prerequisite to the spontaneous use of clustering as a memory organizing device in this task, a finding that has recently been replicated (Tomlinson-Keasey & Crawford, 1976). Haynes and Kulhavy (1976) have also examined recall performance of children at developmental levels defined by their ability to conserve mass, weight, and volume. The authors concluded from the results that more mature subjects have a greater tendency to select and use superordinate information as an encoding device than do children of less cognitive maturity. However, no explicit speculation was made on the relationship between this performance and operations involved in the three forms of conservation. A study perviously referred to (Prawat & Concelli, 1976) examined use of constructive memory (i.e., tendency to recognize correct logical inferences which are implicit in the meaning but not explicitly stated in a series of three statements) by conserving and non-conserving first grade children. From the results the authors offer the tentative conclusion that concrete mental operations may play a general

facilitative role in the constuctive memory process, a role however that may not be tied to the availability of specific schemes. In the final study of this group, Arlin (in press) reports recall data of adolescents following a problem finding task which suggest a relationship between the hierarchical organization of self-generated information in memory and formal operational structures.

With the possible exception of the Tomlinson-Keasey (1975;1976) studies, this small collection of papers illustrates well the difficulties inherent in attempting to apply anything more than the most general aspects of Piagetian developmental theory to the particulars of North American memory research. A common and justified hesitancy was apparent in the willingness of these researchers to specify Piagetian cognitive structures or operations beyond the most general index of developmental level which underlie changes in performance on the memory tasks they examined. The problem is further compounded by the lack of a common terminology both within and between memory and developmental research. The issue of "structure to function" specificity in going from Piagetian theory to paired associate performance is no less a problem in the present research. From the studies of elaboration in paired associate learning reviewed earlier it would appear that those specific cognitive operations which are necessary for the elaboration of noun pairs are functional during the early school years (although with some décalage when abstractness and associative meaningfulness are varied), as evidenced by the ease with which young children can be prompted to carry out these operations. What is to be accounted for by cognitive developmental theory is the growing propensity to spontaneously engage in this type of elaborative activity during adolescence in the absence of external support

for doing so.

Memory and Formal Operational Thinking:

The Piagetian writings (Piaget & Inhelder, 1973) concerning the development of memory have not specifically attempted to relate their conceptions of memory to the changes occuring during the adolescent period with the emergence of formal operational structures. In a recent review of research pertaining to adolescent intellectual development, however, Neimark (1975) made a strong suggestion that such a relationship existed:

> ...the essence of formal thinking lies in organization and compression of information (as represented in terms of more abstract figurative aspects) for more efficient storage, retrieval, and utilization. This type of information organization is reflected not only in performance on the traditional formal operational tasks but also in, for example, deliberate creation of mnemonics, and spontaneous imposition of order on discrete instances and events..." (P. 576)

To pursue this relationship more fully, it is necessary to examine the changes associated with the transition from concrete to formal operational thinking. According to Piagetian theory (Inhelder & Piaget, 1958; Piaget, 1972), the first of these major changes involves the ability to use verbally stated propositions as the elements of thinking rather than having to rely on the manipulation of the properties and relations of concrete referents. Verbal statements can in fact be substituted for objects and can themselves be manipulated as symbolic representations in determining the truth value of "if-then" propositions. This transition allows for higher levels of abstraction and generality to emerge in thinking than was possible

during the concrete period.

The second major change is in the hypothetical-deductive nature of formal thinking. Through the use of the complete combinatorial scheme, the formal thinker is not only capable of subordinating reality to possibility by this ability to generate all possible combinations of variables, or all possible hypotheses, regardless of whether these states actually exist. But he is also capable of deducing the logical consequences or truth value of each of these possibilities through the use of the 16 possible combinations forming a binary combinatorial system, also called the 16 Binary Operations of propositional logic. Such competence in deductive reasoning provides the ability to reason by hypotheses, to apply a general principle or hypothesis to particular cases in order to verify the hypothesis.

The third advancement of formal thinking over the concrete period is access to the structured set of operations called the I.N.R.C. group. This group of operations typifies the capacity at the formal level to carry out "second order operations", or operations on operations. It is the INRC group of operations which also allows the individual to perform operations on propositions themselves without regard to the reality of the content, a point made earlier but worth reiterating in regard to its relation to this operational capacity. In addition, the INRC group allows for the simultaneous coordination of the two forms of reversibility into a single structured whole. With this coordination of negation and reciprocity, the effects of variables within a problem situation can now be examined not only be exclusion, not always possible in physical systems, but also can be neutralized by being held constant. This allows for examination not only of the effect of the variable under question, but also of the influence of other variables

within a single composite system. Thus, the INRC group in combination with the 16 binary operations of propostional logic made available by the combinatorial scheme, provide the total operational structures necessary for hypothesis generation and testing.

In attempting to explore the relationship between adolescent cognitive development and paired associate performance, it is proposed that spontaneous unprompted elaboration in this task may be reliant upon the operations of the formal period in several ways. First, initial evocation of an active approach to the memory task required that the individual apply the general principle or hypothesis that "if later recall is to be insured, means-end actions must be undertaken now", regardless whether the individual has ever experienced a paired-associate task or any other formalized type of memory task before. This situation appears to have some analogue in the construction of formal operational schemes. For example, the links between the operations involved in dealing with a concept such as proportion are established by the individual as a result of his need to interpret the concept in the course of his experience. "When the need is felt, he manages to work them out spontaneously." (Inhelder & Piaget, 1958, p. 308), provided he is capable of using propositional logic.

As a further extension of this, the spontaneous elaborator must be able to make decisions regarding the consequences of possible operations using propostional information. For example, the following situation might have to be considered by the individual: Strategy 'x' is used on an intitial study trial with some pairs but not with others. During the first test trial the individual notes that there are no pairs for which 'x' was applied and the pair was not recalled (i.e., $p.\bar{q}$ where p = a pair for which

strategy 'x' was used, and q = a pair that was recalled). There are cases of all other three outcomes, however (i.e., $\bar{p}.q$, $\bar{p}.\bar{q}$, and p.q). The spontaneous elaborator must be able to use this information to determine if 'x' should be rejected or retained for use on subsequent trials. Ability to perform logical inferences of this type are dependent upon the propositional operations of the formal period.

The spontaneous elaborator must also be able to generate multiple combinations and further combinations of these combinations of components of meaning and of elaborative operations presently in the repertoire in a systematic, task-oriented fashion, and simultaneously deduce the logical consequences of these multiple potential combinations for later recall. He must be able to take the operations for transforming input presently in the repertoire of schemes and combine, modify, and otherwise operate upon these to produce new operations suitable for the specific recall task at hand. The ability to coordinate these multiple operations within a unified system from which logical deductions can be made concerning consequences appears to be of the sort that Piaget has referred to as 'Second Order Operations' or 'Interpropositional Operations', a competency which emerges with the coordinated functioning of the combinatorial system and the INRC group of operations. (Inhelder & Piaget, 1958)

Finally, and particularly with reference to the elaboration of abstract nouns, the spontaneous elaborator must be capable of generating hypothetical situations or referential events which may never have been experienced or which may have no empirical reality, and must additionally be able to do so when these attributes represent abstractions or components of meaning which have no specific external referents. It is the combinatorial system

and the propositional logic of the formal period that frees thinking from the confines of empirical reality, using this reality simply as a springboard for speculation about "all possibles" (Inhelder & Piaget, 1958).

If the above analyses are logically valid, then much of the age related variance in spontaneous elaboration during the later childhood and adolescent period should cease to exist if variance associated with formal operational abilities can be partitioned out. The present research sought to subject this issue to empirical analysis.

Assessment of Formal Thinking: In undertaking an examination of this relationship between spontaneous elaboration and formal thinking one is faced with what might be characterized as the most often criticized and unsettled aspect of Piagetian theory - the empirical status of formal operational thinking. First, the issue of the universality of formal thinking has been seriously questioned. In the original statement of the theory (Inhelder & Piaget, 1958) formal thinking was said to develop during the ages of 11 and 15 with equilibration achieved in 75 per cent of adolescents by 15 years of age. A considerable body of research has failed to support this contention however, with percentages rarely exceeding 55 to 60 per cent even among college students (Dale, 1970; Dulit, 1972; Jackson, 1965; Lovell, 1961; Ross, 1973; Tisher, 1971; Tomlinson-Keasey, 1972). For example, conservation of volume, generally characterized as a very early emerging formal operational competency shows considerable lack of universality with 60 per cent of college students (Elkind, 1962; Towler & Wheatley, 1971), 47 per cent of high school students (Elkind, 1962), and 25 per cent of grade six students (Elkind, 1961; Uzgiris, 1964) demonstrating success with this concept.

A restatement of the Piagetian position concerning this issue has recently been made (Piaget, 1972):" ... all normal subjects attain the stage of formal operations or structuring if not between 11-12 to 14-15, in any case between 15 and 20 years. However, they reach this stage in different areas according to their aptitudes and their professional specializations (advanced studies or different types of apprenticeship for the various trades): the way in which these formal structures are used, however, is not necessarily the same in all cases." (p. 10). This restatement does little, however, to instill renewed confidence in the researcher attempting to assess formal thinking with some measure of standardization. As Ross (1974) has made clear, if the formal structures are manifested differently within a particular aptitude context, then it would first be necessary to identify each individual's superior aptitude and then assess performance in tasks which are congruent with it.

The situation is made into even more of a measurement problem by the second empirical issue of controversy, inconsistency of performance across tasks. This lack of consistency of performance across the various Inhelder and Piaget tasks has been repeatedly demonstrated (Dockerty, 1975; Jackson, 1965; Lovell, 1961; Lovell & Shields, 1967; Neimark, 1970; Ross, 1973; Tomlinson-Keasey, 1975) and poses a severe challenge to the construct validity of formal operations as presently conceived. Lovell's (1971) overall conclusion after ten years of research into this issue of consistency was that one should not anticipate an index of concordance among the various Inhelder and Piaget tasks to be in excess of .50. A related issue is the degree to which formal thinking is generalizable across various content areas and task variables. For example, Berzonsky, Weiner, and Raphael (1975) report lack of a significant relationship between two tasks

requiring logical thinking skills (concept attainment and verbal syllogisms), while Neimark (1970) found inconsistent patterns of relationships between several of the Inhelder and Piaget tasks and logical problem solving. Lovell (1975) in a recent review of research concerning this issue notes that such factors as familiarity with the materials, interest, and attitude toward subject matter all influence the degree to which formal thinking is manifest in performance. Similarly, Ross (1974) has reported that the degree to which problems are ego-involving or require ethical decision-making influences the likelihood that formal thinking will be operational. Again, one can refer to the recent restatement of the Genevan position (Piaget, 1972) which has been modified somewhat to allow for some intraindividual inconsistences across tasks. "Briefly, we retain the idea that formal operations are free from their concrete content, but we must add that this is true only on the condition that for the subjects the situations involve equal aptitudes or comparable vital interests." (p. 11). From an assessment standpoint then, if the research is to maximize the probability that formal competencies are manifest in performance, tasks must be concomitant with each individuals particular aptitudes and must be of equivalent motivational value.

In addition to the above concerns regarding assessment of formal thinking, research has been ambiguous with regard to sex differences in performance on measures of formal thinking. While several investigations find males superior to females on a number of such tasks (Dale, 1970; Dulit, 1972; Elkind, 1962; Ross, 1973) no such sex differences have been found by others (O'Brien & Shapiro, 1968; Uzgiris, 1964). The general trend in this research would seem to be an increasing tendency toward male superiority of performance as age increases.

Finally, as well as these problems of lack of universality of acquisition of formal structures, inconsistency of performance across tasks and content areas, and the seeming uneveness of development across the sexes, methodological problems associated with the use of the Inhelder and Piaget tasks (i.e. importance of precise and dependable apparatus, lack of clear standardization and scoring of protocols, time-consuming nature of procedure) must be contended with by the researcher. In response to these difficulties, attempts have been made by a number of researchers either to develop more standardized administration and scoring of the original Inhelder and Piaget tasks, in some cases with group administration and paper and pencil responding (e.g. Howe & Mierzwa, 1976; Nolen, 1976; Ross, 1975; Tisher, 1971; Tomlinson-Keasey, 1975) or to develop alternative tasks which assess presence of formal structures (e.g. Fishbien, Pampu, & Marzat, 1970; Karplus & Karplus, 1970; Karplus & Peterson, 1970; Neimark & Lewis, 1967; 1968; O'Brien & Shapiro, 1968; Peel, 1971; Sills & Herron, 1974). Unfortunately, only isolated attempts to establish relationships of a psychometric nature between these measures and the traditional formal tasks of Inhelder and Piaget (1958) have been undertaken.

From the foregoing it is apparent that one cannot rely upon performance on a single task, whether it be one of the original Piagetian measures or some other means of assessment of formal structures, if one is to establish the existence of general formal competence not totally biased by situation-specific variables. Neimark (1975) in considering the problem of the selection of appropriate measures of assessment of formal thinking cautions the researcher:

> In the case of research addressed to Piaget's theory of formal operations, this means that, as a minimum, one selects dependent

> variable measures that are valid indices of formal operations. This, in turn, requires careful consideration not only of the measures to be obtained but also of the appropriateness of the task and the representativeness of the groups employed (p. 573)

In the present research it was proposed earlier that the particular competencies which the formal operational individual has that are relevant to spontaneous elaboration of paired associates are abilities to generate multiple solution hypotheses in the form of mnemonic strategies, to carry out empirical testing of these, and to modify the mnemonic consonant with the results of these efforts. In addition, these abilities must be applicable to verbally stated problems devoid of concrete referents which can be directly interacted with.

The requirement then, was for an instument that met the following criteria: the items assessed combinatorial operations and propositional thinking; the items had a demonstrated relationship with Piagetian formal operational tasks; the format was appropriate for children in the 12 to 18 year age range; the instrument could be managably administered and scored for in excess of 250 individuals. Due to the last requirement, special attention was paid to existing group administered measures which allow for paper and pencil responding. Following Neimark's (1975) suggestion, the proposed test battery included two formal operational conservation problems (volume and density) in addition to one concrete conservation task (weight). The inclusion of these items provided a general index of developmental level on tasks for which general agreement exists concerning structures for solution. In addition, volume conservation is considered to mark the early emergence of coordinated functioning of the INRC group (Brainerd, 1970;1971;

Neimark, 1975). Nolen (1976) has recently developed and reported use of a paper and pencil version of occupied volume conservation and her form is easily adaptable to group administration, in coordination with the procedure for individual administration specified by Brainerd (1971).

For purposes of assessing combinatorial thinking, the chemicals task of Inhelder and Piaget (1958) was the obvious choice. Tomlinson-Keasey (1975) has developed a strictly paper and pencil version of this task which she has used with college students and has found results to generally parallel those of other individually administered formal tasks. This problem set allows one to examine the subject's strategies in generating combinations, their ability to draw conclusions, and their ability to generate critical tests. While the questionaire and scoring format used by Tomlinson-Keasey will be employed in the present assessment instrument, there was some concern for the degree of clarity of the problem in its present form for the younger children examined in this research. To remove any possibilities of misunderstanding it was felt wise to supplement the questionaire form with demonstrations of the equipment at various points in the testing session, a group administration procedure which has been found to produce 75 per cent agreement in group versus individual assessment of formal thinking (Ross, 1974; Tisher, 1971).

For the assessment of propositional thinking, two versions of the logical implications problems initially developed by Peel (1971) were selected for use. This decision was justified in part by the fact that these items have been characterized as "...an alternative to the hidden magnetism task which Inhelder and Piaget used to study the 16 binary operations of logical thought" (Arlin, in press), and have been consistently

found to be directly related to traditional measures of formal thinking (Arlin, in press; Nolen, 1975). These problems present the child with data (the existence of cases of the form $p.q$, $\bar{p}.\bar{q}$, and $\bar{p}.q$, phrased in real-life contexts) which appear to be sufficient for establishing a conditional relationship between two propositional functions, p and q. The child is then expected to recognize that no definite propositional conclusion can be drawn without knowledge of the existence or non-existence of cases of the form $p.\bar{q}$.

Nolen (1976) has developed and tested both a constructed answer and a multiple choice format of these two problems and has found the latter to be less stringent in testing logical reasoning. In addition, one of the problems which concerned the influence of compensatory language programs on language achievement of "Headstart" children was judged to be of content with which many of the Canadian children tested in this research would be unfamiliar. For this reason, the problem was substituted by one of identical form but whose content referred to a summer hockey school and subsequent goal-scoring behavior, in an attempt to place it in a more Canadian context. This change seems doubly justified in light of Piaget's caution that problems must be of high familiarity and interest to subjects if formal thinking is to be demonstrated. The exact form of these problems can be found in Appendix B.

CHAPTER III

Methodological Considerations

Method

Subjects: In their original investigation of spontaneous elaboration Rohwer and Bean (1973) found clear evidence of a developmental trend only among students sampled from a high SES population. As one of the intents of this research was to attempt to replicate these findings, particular care was taken to sample from a like population. Students involved in this research were enrolled in one elementary and one secondary school within the West Vancouver School System. All students were from a residential district identified as having the highest income level of any census tract in the province (Statistics Canada, 1970). A total of 279 students in grades 6, 8, 10, and 12 were administered the formal operations instrument (FOI). This number included 47 grade 6 students, 85 grade 8 students, 73 grade 10 students, and 74 grade 12 students, with approximately equal numbers of students of each sex at each grade. The grade 6 students were members of two intact classes, while the students in the other three grades were members of three social studies classes within each grade level. All students were enrolled in academic college preparation programs. One male in each of the older two grades was subsequently dropped from participation when it became apparent that they were new Canadians from non-English speaking homes. From this initial pool of subjects 18 students of each sex within each grade level were selected to serve in the paired associate learning phase of the research. Selection procedures are described below.

Design: A 4 x 3 factorial design was used with treatment groups (control, repetition, trained) nested within grades (6, 8, 10, 12). Trials (3), noun pair concreteness (concrete (C), abstract (A)), and level of

associative meaningfulness within concreteness (CL, CH, AL, AH) were treated as within subjects variables. The use of three study-test trials was considered desirable, given the significant trials effect of previous research (Greer & Suzuki, 1976). Within each of the four grade levels six triads of same-sexed students were formed by matching on the basis of FOI total score and age in months. One member of each triad was then randomly assigned to each of the three treatment groups. In the assignment of these triads, attempts were made to have the mean age and FOI score of each treatment group as equivalent as possible, as well as being as representative of the overall grade mean on these two indices as the sample would allow. The final make-up of each group by grade and sex is summarized in Table I.

The control group was identical to Rohwer and Bean's (1973) minimal prompt group in that subjects were simply instructed to pay attention and to do their best to remember the pairs. The repetition group was instructed to learn the pairs by rehearsal and was required to repeat each pair overtly during the ten-second interitem interval of the study trials. In the trained group instructions and practice in the use of both interactive imagery and verbal elaboration was provided prior to the first trial of the memory task.

Materials

Paired Associate List: The 32 nouns (16 concrete, 16 abstract) making up the 16-item paired associate list were selected from among a pool of 96 nouns for which *m* data for grades 6, 8, and 10 had been previously collected using Nobel's (1952) procedure (Greer & Suzuki, 1976). These 32 nouns were selected so that eight of the nouns within each level of concreteness were significantly lower in mean *m* at each grade level than were the remaining eight. Thus, the eight concrete low *m* (CL) pairs were significantly lower

Table I

Experimental Design

	Grade 6		Grade 8		Grade 10		Grade 12	
	Male	Female	Male	Female	Male	Female	Male	Female
PHASE I								
n	26	21	44	41	39	34	35	39
M Age	140	140	164	162	187	187	214	209
S.D.	4.20	3.58	4.49	3.87	5.76	7.56	6.12	4.36
M FOI	31.50	35.19	36.32	42.29	43.53	40.76	46.65	46.64
S.D.	11.10	8.72	9.26	6.63	6.87	10.82	7.98	7.50
PHASE II								
Control:								
n	6	6	6	6	6	6	6	6
M Age	143	141	164	164	188	184	211	208
S.D.	4.18	2.73	2.66	2.45	1.87	7.88	2.53	4.92
M FOI	34.50	35.83	41.33	44.00	47.17	42.33	48.17	44.50
S.D.	9.61	10.01	6.28	5.51	7.55	9.97	4.49	5.50
Repetition:								
n	6	6	6	6	6	6	6	6
M Age	141	139	163	163	188	188	214	208
S.D.	4.05	4.26	2.97	2.14	8.31	4.14	7.60	3.58
M FOI	34.17	35.00	44.17	42.83	46.33	45.17	47.33	47.00
S.D.	9.37	6.99	9.62	7.19	4.46	10.63	3.08	6.26
Trained:								
n	6	6	6	6	6	6	6	6
M Age	140	140	164	163	183	189	214	210
S.D.	3.78	4.54	4.83	2.43	4.96	3.92	3.92	3.22
M FOI	35.33	35.17	42.00	42.83	45.83	44.50	47.17	47.50
S.D.	7.94	9.06	6.16	6.40	5.04	8.83	5.91	5.28

Note. M FOI = Mean total score on Formal Operations Instrument. Total possible score = 63

in mean m than the eight concrete high m (CH) pairs at each grade level. Likewise, the eight abstract low m pairs (AL) were lower in mean m than the eight abstract high m (AH) pairs.

It was not possible to select items that allowed for examination of the influence of abstractness independent of level of meaningfulness in the list as a whole because of the strong negative relationship between abstractness level and m at all three grades. In selecting items, however, it was possible to achieve equivalence in m levels among the eight CL and the eight AH nouns. Thus, within the total noun pair list this subset of pairs allowed for examination of the influence of abstractness level on memory performance independent of meaningfulness level.

The final list of 16 pairs was constructed by random pairing of the nouns within each concreteness and m level combination. The resulting list is presented in Table II. A detailed account of the item selection procedures and statistical analysis of the list characteristics is reported in Appendix A. All pairs for study trials and stimulus nouns for test trials were prepared on color slides, with all letters typed in upper case.

Training Materials: For training purposes four concrete and four abstract noun pairs were constructed from among the unused nouns of the original 96. These pairs included: desk-boat, scissors-candle, telephone-string, railroad-strawberry, cost-duty, interest-anger, belief-chance, life-glory. Each pair and each stimulus noun alone for the practice study and recall trials, respectively, were printed on white index cards. In addition, for the concrete pair 'desk-boat' a simple line drawing of a desk with a small boat on it was prepared on one card, and the sentence "The desk has a boat on it." was printed on a second card. For the abstact pair 'cost-duty', an interactive image of a broom with a price tag marked 10¢ was

Table II

Structure of Paired Associate List

Pair Type	Item Pair		Mean m and S.D. by Grade 6	8	10
Concrete Low m (CL)	pipe	barrel			
	star	fork	5.42	7.00	7.35
	iron	flag	±.59	±.77	±.60
	hammer	doll			
Concrete High m (CH)	fire	apple			
	flower	house	7.54	9.54	9.60
	tree	baby	±.49	±.75	±1.01
	ship	bird			
Abstract Low m (AL)	method	shame			
	pride	fate	3.04	4.19	4.39
	ability	truth	±.32	±.60	±.53
	fault	opinion			
Abstract High m (AH)	science	death			
	devil	time	5.55	7.79	7.22
	love	dream	±.64	±.84	±.76
	law	fun			

prepared on one card, while the sentence "It will cost 10¢ if you miss your cleaning duty." was prepared on a second card.

As part of the materials used during a post-task interview, two duplicate sets of the pairs used during the memory task were prepared on 3 × 5 inch index cards, one pair per card. Six envelopes were also prepared, each bearing one of the following labels: "Easier to remember", "Harder to remember", "PICTURE", "SENTENCE", "REPEAT", and "NOTHING".

Formal Operations Instrument(FOI): This test was designed to allow for paper and pencil responding to a number of group administered Piagetian tasks of formal thinking as well as a test of propositional thinking designed by Peel (1971). The instrument was composed of three major sections: A. Conservation problems; B. Combinatorial thinking; C. Propositional logic. Throughout the administration of these items each student wrote his/her answers on response sheets prepared for this purpose (see Appendix B.). The set of 12 sheets was provided in an envelope that showed only the page number of each subsequent sheet while still in the envelope. On completion of each page, the class was instructed to fold it and place it in the back of the envelope behind pages yet to be removed. In this manner attempts to add to, change, or otherwise modify earlier responses were inhibited. Understanding of this procedure to be used with the answer sheets and envelope was made clear at the onset by having each student complete page 1 (name, sex, grade, age), then fold and place it into the back of the envelope before the presentation of the first test item.

A. Conservation: This section of the instrument included items to assess conservation of weight, volume, and density and thus spanned the later concrete and early formal periods in terms of operations required (Brainerd, 1970; 1971). The procedure and scoring were adapted from those

employed by Brainerd (1971) in individual assessment of these conservations, in combination with the group administration approach employed by Ross (1975), Tisher (1971) and Nolen (1976). In this procedure the task and equipment are demonstrated by the experimenter to the class as a group. Questions to be answered are posed to the group with each child responding on his own answer sheet.

Equipment and Procedure: A large beaker half filled with water, two 50-gram balls of rubber-based clay, an elastic band, a double-pan balance scale, two test tubes half filled with water in a test tube rack, one solid aluminum cube (1 cm) and one solid brass cube (1 cm) constituted the equipment required for the three conservation tasks.

(1) Weight: The class was shown the balance scale and the two clay balls. One ball was placed on each side of the scale in the pan with the explanation that if two objects of equal weight are placed on the balance, the pans will be level and at the same height. One student was called upon to verify that the two pans were at equivalent heights, or to make adjustments to the size of the clay balls as required. One ball was then removed and flattened to form a pancake. At this point the class was instructed to remove page 2 from their envelopes. The first question was read to the class with the reminder that no student was to call out the answer but each was to think of the answer silently in his head. The class was asked:

> If I put this flat piece of clay back on the scale will the two pans still be at different heights? Pick up your pencil and circle the answer that you think is correct. Then write down a brief explanation or reason why you think that is the correct answer. When you have finished answering that question, go on to the second question that is right below the first one. When you have finished answering both questions, fold the sheet in half and place it in your envelope behind the other sheets.

Sufficient time was allowed for all students to finish writing. When all students had placed their completed response sheets into the back of the envelopes, the conservation of volume task was presented.

(2) Volume: The round clay ball was removed from the balance and the beaker of water was brought forward. The clay ball was placed into the water and the rubber band was placed around the beaker marking the level of the water. A student was called upon to verify the level of the band. The clay was then removed, making sure that no discernable amount of water was removed with the ball. The clay was rolled into a sausage shape in front of the students, and then instructions were given to remove page 3 from the envelopes. The first question on volume was then read to the class, again with the reminder that each person was to answer on his own silently:

> If I place the sausage in the glass, will the water go above the rubber band now? Circle the answer you think is correct. Then write a brief explanation or reason for your answer. When you have finished this question, go on to complete the remaining two questions on this page. When you have finished all three questions, fold the sheet in half and put it into the back of your envelope. Then we will go on to the next problem.

Following this the two test tubes in the rack were brought forward and a student was called upon to verify that the water level was identical in the two. Another student was given the two metal cubes and asked if both were the same size. When this was affirmed, the student was asked if they were the same weight. When this was answered in the negative, the aluminum cube was placed into one of the test tubes and it was pointed out that the water was now higher in this test tube. Students were then instructed to remove the next page from their envelopes, and read:

> Here are two test tubes filled with equal amounts of water and two metal cubes, one made of aluminum and the other of brass. The aluminum and brass cubes are exactly the same size, but the brass cube is heavier. When the light aluminum cube is put into

> one of the test tubes, the water comes up the test tube part way. If the brass cube is put into the other test tube how high will the water come up? Draw a line on the test tube to indicate how much the water will rise. Will it come up about the same amount as the one containing the aluminum cube, or even higher, or lower? When you have drawn a line to show how high you think it will come up, then briefly explain your answer. When you have finished writing fold your answer sheet in half and place it in the back of the envolope.

When all students had replaced their answer sheets in the envelope, the density conservation task was presented.

(3) Density: The clay ball used in volume conservation was placed into the beaker (with the elastic band removed) and the class observed it sink to the bottom. The ball was removed and flattened into a pancake shape. This piece of flat clay was then held up so that the class could observe it from all sides and note that it was flat and about one third inch thick. The class was instructed to remove page 5 from their envelopes and read the following:

> Do you think this piece of clay will float? Circle the answer you think is correct and write a brief explanation for your answer. Then fold your sheet in half and put it into the back of your envelope. When everyone has done so, we will go on to the next question.

When it was assured that all students had placed their answer sheets in the envelope, the clay was placed back into the beaker and the class observed it sink to the bottom. The clay was then removed from the water and approximately 3/4 of the clay was cut off with scissors, leaving a flat, moon-shaped piece. Students were instructed to remove the next page from their envelopes:

> If I put this piece of clay that is left over into the water will it still sink? Circle the answer you think is correct and write a brief explanation for your answer. As soon as you have finished, fold your sheet in half and return it to the back of your envelope.

When all students had placed answer sheets back into the envelope, the clay

was placed into the beaker and the class observed it sink to the bottom. Again the clay was removed and a small section approximately 2 mm long and 1/2 mm wide was cut off. One student was called upon to verify the approximate size and shape of this piece. Students were instructed to remove next page from envelopes, and read the following:

> If I put this little piece into the water now, will it float? Circle the answer you think is correct and write a brief explanation for your answer. As soon as you have finished, return the sheet to your envelope.

When all students had done so, the class again observed the piece of clay placed into the beaker and sink to the bottom. Instructions were then given to remove page 8 from the envelopes and to complete this last item on density conservation, and to return sheets to envelopes, when completed.

Scoring: Scoring of these items was based on the procedure used by Brainerd (1971). Correct answers to questions were assigned a score of 1 while incorrect responses receive a zero. This scoring system results in a three-point range for weight (0-2), a five-point range for volume (0-4), and a five-point range for density (0-4). The scoring of explanations will again use Brainerd's five category system. Rationales are classified according to the following system:

1. Inversion reversibility: Perceptual deformations can be reversed (Note. Not applicable to density conservation).
2. Reciprocal reversibility: Changes in one dimension are compensated by changes in a related dimension; equivalence explanations: i.e., "They are just the same weight" fall into this category.
3. Conceptually irrelevant explanations: Use of irrelevant perceptual features of the stimuli; i.e., "It is the weight

that makes it so.", as an explanation for volume of density conservation.

4. Deceptive perceptual features of the stimuli: i.e., "It's skinnier so it must take up more room."

5. Don't know: no explanation.

Explanations in category 1 and 2 were classified as conserving and given a score of 1; those in categories 3, 4, and 5 were assigned a zero. The total possible score for weight was 4, and for each of volume and density was 8.

B. Combinatorial Thinking: This task used the group administration procedure of the colorless chemicals task along with the written format and scoring procedure developed by Tomlinson-Keasey (1975).

Procedure and Equipment: The equipment included five bottles of colorless liquids clearly labeled as below. Each contained the following:

Bottle 1) Dilute sulphuric acid
Bottle 2) Water
Bottle 3) Hydrogen peroxide
Bottle 4) Sodium thiosulphate solution
Bottle "g") Potassium iodine solution

The last bottle "g" was smaller than the remaining four bottles. All five were equiped with a dropper. Two beakers, one which contained liquids 1 and 3 (labeled "A") and the other liquid 2 (labeled "B") were prepared in advance. As with the original version of this task, when 1 + 3 + g were combined a yellow solution resulted ; 2 had no effect; 4 removed or prevented the color. Other equipment included 15 test tubes and two test tube racks; 15 cards with large black lettering indicating each of the 15 possible combinations with "g" and a pin board divided into two sections headed YES and NO.

The task was introduced by explaining that each of the bottles contained a different chemical and that the last bottle "g" was an activating solution.

Then the two beakers A and B were brought forward with the explanation that they contained some of the chemicals that are in the bottles but that their identity will be kept a secret. Several drops of "g" were then added to each beaker with the result that A turned yellow while B did not. The class was then told that their problem was to find what combination of chemicals with "g" would make the yellow color. At this point the students were instructed to remove page 9 from their envelopes. This page instructed the student to list all the possible combinations of the chemicals mixed with "g" which they would test in an attempt to identify which ones turn yellow. Instructions were given to complete this question and then to return the sheet to the back of their envelopes. The example "1 + g" was written on the black board in the classroom as an example of the format which was to be used in answering this question.

When all students had indicated completion, the experimenter conducted each of the 15 combinations, going in logical order through each of the one-way, two-way, three-way, and the four-way combinations. As each test was conducted the card for that test was placed on the pin board to indicate if the color was produced or not (i.e. under YES for yellow color produced, and under NO for no color). The results, of course, were all combinations but 1 + 3 + g and 1 + 2 + 3 + g under the NO side of the pin board. When all tests had been completed, students were instructed to remove page 10 from their envelopes and complete the four questions posed. This page presented a summary of the results of the 15 tests analogous to that created on the pin board. Students were directed to complete the four questions to the best of their ability and to return the page to their envelopes.

Scoring: Procedures for scoring followed that suggested by Tomlinson-Keasey. On the first question, one point was given for each different

combination generated to a total possible score of 15. On the second page of the task, a correct score of 2 was given to Question 1 if it indicated that chemical number two had no influence on the reaction, and a correct score was given on question three if it stated that chemical number four inhibited or neutralized the reaction. To receive a correct score of 2 on questions two and four, the answer must test 1 + 3 + 2 + g and 1 + 3 + 4 + g respectively. Thus, the total score was 23 for the two parts of this task.

C. Propositional Thinking: There were two logical implications problems, refered to henceforth as the Hockey and the Rose problems. The Rose problem was presented to the students immediately before the chemicals task so that students could work on this problem while the experimenter was preparing the equipment for the chemicals task. The Hockey problem was completed immediately following the chemicals task. Instructions were given to remove the page from the envelope and to follow along while the problem was read by the experimenter. Students were cautioned to think carefully about the problems before responding and to try to explain their choice of a yes or no answer in some detail. Approximately five minutes was allowed for each of these questions. Scoring of explanations was according to the category system, explanations were categorized into five levels:

Category 1: Strict Logical Analysis: Example-No, the writer does not say that he saw sprayed leaves which were unhealthy. Therefore nothing definite can be said.

Category 2: Logical Causal Analysis: Recognition of the ambiguity of the statements. Example-No, as some of the unsprayed leaves were not diseased we cannot say definitely if the spray made the other leaves healthy.

Category 3: Assumptions of Implication: Students assumed

that there were no unhealthy, sprayed leaves. Example-Yes, some definite effect, sprayed leaves were healthy while the unsprayed ones were not all healthy.

Category 4: Content-circumstance Dominated. Example-Yes, the spray when applied to the leaves was effective to one set of leaves but not to the others.

Category 5: Residual: Irrelevancies, tautologies, inconsistencies. Example-No, you have to spray your garden or the bugs will eat the leaves.

Assigment of numerical values was as follows: 2 points for correct "no" decisions to each problem. For explanations, Category 1 = 8 points, Category 2 = 6 points, Category 3 = 4 points, Category 4 = 2 points, Category 1 = 0 points. Thus, the total possible score on these two problems was 20.

The same scoring criteria as were used for the Rose problem were also applied to the Hockey problem. Classification of explanations into response categories was undertaken by the experimenter plus one additional person familiar with the system.

A full description of the results of pilot testing of this assessment instument is provided in Appendix C.

Procedure

Formal Operations Instrument (FOI): Administration was undertaken in existing classroom groups averaging approximately 26 in number. Order of presentation of the items was as follows: (1) Conservation: weight, volume, density; (2) Peel's Rose problem; (3) Chemicals Task; (4) Peel's Hockey problem. The average duration of the testing sessions for grades 6, 8, 10, and 12 were 75 minutes, 60 minutes, 50 minutes, and 45 minutes respectively. No students at any grade level (with the exception of the two non-english

students refered to above) failed to make some response to all questions. Care was taken to guard against any collusion among students by having an additional observer in the room at the time of testing. In all cases this was the regular classroom teacher.

Memory Task: All students were tested individually in a quiet room separate from the classroom. The child was seated directly across a table from the experimenter and a general introduction to the requirements of a paired associate task were given, followed by the training session. The control group was simply instructed to concentrate and try to do their best to remember each pair. Practice study and test trails were given with the six training pairs until at least four out of six items were correctly recalled. All study and test trials were presented via a Coxco synchronized sound slide projector. A 10-second interitem interval was used for each study trial while on test trials this interval was five seconds. During the test trials all oral responses were recorded by the experimenter.

For the repetition group, instructions were given in the use of repetition of item pairs during the interitem interval of the study trials. Practice study and test trials were given with the training pairs until four out of six items were recalled, with the requirment that overt repetition be used during the study trials.

For the trained group instructions were given in the use of interactive images and sentences containing the pairs as effective methods for improving subsequent recall. The card containing the concrete pair "desk-boat" was placed before the subject. It was explained that it would be much easier to remember that "desk" goes with "boat" if the two words are 'locked together in a single thought' during the study trial. As an illustration of this concept, the card showing the line drawing of a desk with a boat on it was

presented. It was pointed out that the two words could be 'locked together' by thinking of a single image or 'picture inside your head' which contained something to represent each of the two words. "Then when the word "desk" is presented alone, it will make you think of the picture of a desk with a boat on it, and you will be able to say "boat" during the test trial". As a further illustration of image-generation, the pair "cost-duty" was presented with the explanation that some pairs may not immediately suggest an image. It was further suggested that such pairs might serve as reminders of some event that happened in the past. To illustrate this concept, the experimenter explained that these two words reminded her of past experiences at summer camp. Each camper was required to take turns at cleaning duty, and if this duty was forgotten then a fine of ten cents had to be paid. Thus, the two words "cost-duty" made her think of a picture of a cleaning broom to represent "duty" and a price tag of ten cents to represent "cost". At this point the line drawing representing the image of a broom with a ten cent price tag attached was presented.

The experimenter went on to suggest that if a picture did not come to mind when the pair was presented, another effective way to "lock the two words together" was to make up a sentence or phrase which contained the two words. The two cards containing the sentences "The <u>desk</u> has a <u>boat</u> on it." and "It will <u>cost</u> 10¢ if you miss your cleaning <u>duty</u>." were added to those representing interactive images. Following this the subject was given practice with the remaining six pairs until either a sentence or an interactive image had been produced and reported for each pair. Encouragement was given as required to ensure that each subject attempted to use both modes of elaboration. Practice study and recall trials were then given with the six pairs until the criterion of four correct responses was reached.

Following completion of training, the Coxco apparatus was placed on the table between the experimenter and the child. Its use as a means for presenting material was explained and a slide was shown that was not part of the memory task itself. Specific instructions regarding the task were then given via the audio portion of the apparatus. The subjects were informed that they would be attempting to learn 16 pairs in total and would have three alternating study and test trials. They were cautioned that order of pairs in the list would change from trial to trial and that they should disregard order and concentrate on trying to learn which words go together to make each pair. Each set of one study and test trial was interupted long enough for a new slide tray to be placed into the Coxco (about 15 seconds). Between each study and test trial one blank slide was inserted and the announcement was made from the tape "You have just finished your first (second, third) study trial. We will now begin your first (second, third) test trial". The order of presentation of items was constant for all subjects. This order was determined for each study and test trial by randomly selecting one pair of each of the four types (CL, CH, AL, AH) to appear in each trial quartile. It was insured however, that no item which appeared among the last four pairs of a study trial be among the first four slides of the next test trial. A full transcript of the audio portion of the paired associate task is provided in Appendix D.

On completion of the last test trial, each subject was interviewed regarding use of mnemonics during the task. To facilitate this process, the first deck of cards containing the 16 pairs was given to the student along with two envelopes, one labeled "Harder to remember" and the other labeled "Easier to remember". The student was requested to sort the pairs into two piles according to these categories. During this sorting procedure

information was sought regarding what the subject thought contributed to making an item difficult or easy to remember.

Once this sorting task had been completed, the envelopes were removed and the second deck of 16 cards was presented along with the four envelopes labeled "Nothing", "Repeat", "Image", and "Sentence", respectively. For subjects in the trained group the instructions were given to sort the pairs into the appropriate image or sentence categories to indicate which method they had used to learn each pair. They were told to use the repeat category only to indicate pairs for which they had not used any method other than saying the pairs twice or more in their heads. The "Nothing" category was to be used to indicate pairs for which they had done nothing other than look at and listen to their presentation.

For the repetition and control group subjects, these specific instructions were prefaced with the following general orienting instructions (statements enclosed within parentheses were given only to the repetition subjects):

> Other students who have taken part in this kind of memory task in the past have told me that they used some special tricks or things that they did inside their heads ot help them to remember at least some of the pairs. (I showed you one way to help yourself to remember and asked you to try repeating the two words and not to do anything else, but) maybe you used some of these (other) methods with some of the pairs (as well). I would like you to tell me what (else) you did (as well as repeating) to help yourself remember. These categories I have here might help you to think about what you did for each pair.

When the subject had completed sorting all 16 pairs, the cards were removed

and the following question was asked: I would be very interested to know if anyone has ever told you before about ways to make information easier to remember. Has any teacher? or perhaps your parents? friends? ever told you anything like that? The format of this short interview was left very open-ended, barring inclusion of the above question. Responses were recorded by the experimenter and any examples, comments, or relevant instances reported by the subject were noted in brief.

CHAPTER IV

Results

Formal Operations Instrument FOI

A summary of the item mean scores by sex and grade is presented in Table III. Multivariate analysis of variance was performed on these data to examine significant trends in performance across grades in addition to differences in sex within grades. After the multivariate tests were performed considering all item scores simultaneously, univariate tests were performed on each of the seven variables separately. A separate univariate analysis was performed on the linear combination of all seven scores (i.e. total score) as well. From the results of these analyses presented in Table IV, it is evident that the performance across grades was clearly linear by both the multivariate and univariate tests. Significant sex differences were indicated by the multivariate tests at all but the grade 12 level. From the univariate tests it can be seen that for grade 6 students this difference was in the number of combinations generated to the chemicals task, with females (M = 12.23) exceeding males (M = 9.85). At the grade 8 level the females significantly out-performed the males on both combinations generated (Females M = 12.85; Males M = 10.80) and on the Hockey problem of the propositional logic set (Females M = 5.76; Males M = 4.46). In addition the total scores of the grade 8 females (M = 42.29) was significantly higher than that of the males (M = 36.32). At the grade 10 level significant univariate tests were found associated with volume conservation and hypothesis testing in combinatorial thinking. In both cases males exceeded females with means on the former task of 6.87 and 5.41 and on the latter task of 4.53 and 3.32 for males and females, respectively.

To examine the nature of the distribution of scores over the four grade levels, the percentage of subjects at each grade level whose total score

Table III

Mean Item Scores of the Formal Operations Instrument by Grade and Sex.

	Grade	Males		Females		Overall	
		M	S.D.	M	S.D.	M	S.D.
Weight (4)[a]	6	3.04	1.54	3.05	1.66	3.04	1.57
	8	3.02	1.45	3.41	1.32	3.21	1.40
	10	3.53	1.27	3.26	1.48	3.40	1.37
	12	3.88	.69	3.79	.77	3.84	.73
Volume (8)	6	5.42	2.82	4.62	2.56	5.06	2.71
	8	5.34	2.56	5.85	2.28	5.59	2.43
	10	6.87	1.66	5.41	2.46	6.18	2.19
	12	6.79	2.07	6.85	1.90	6.82	1.97
Density (8)	6	4.27	1.37	4.14	1.11	4.21	1.25
	8	4.73	1.72	5.39	1.74	5.05	1.75
	10	6.37	1.75	5.91	1.80	6.15	1.77
	12	5.95	1.87	6.36	1.48	6.16	1.68
Combinatorial Thinking: Combinations (15)	6	9.85	3.45	12.23	2.74	10.91	3.34
	8	10.80	3.19	12.85	1.85	11.79	2.81
	10	12.50	2.68	11.74	3.41	12.14	3.05
	12	13.62	2.28	12.92	2.12	13.25	2.21
Combinatorial Thinking: Hypotheses (8)	6	2.77	1.97	3.24	2.05	2.98	1.99
	8	3.04	2.33	3.46	2.10	3.25	2.22
	10	4.53	2.82	3.32	2.50	3.96	2.72
	12	4.88	2.16	3.95	2.49	4.38	2.37
Propositional Logic: Hockey (10)	6	3.08	3.11	4.38	3.14	3.66	3.16
	8	4.46	2.55	5.76	2.50	5.08	2.59
	10	5.11	2.58	5.82	2.89	5.44	2.73
	12	6.00	2.65	6.62	2.35	6.33	2.49
Propositional Logic: Rose (10)	6	3.08	2.35	3.52	2.89	3.28	2.59
	8	4.73	2.90	5.22	2.52	4.97	2.72
	10	4.84	2.66	5.24	2.74	5.03	2.69
	12	5.53	2.36	6.15	2.44	5.86	2.41
Total Score (63)	6	31.50	11.10	35.19	8.72	33.15	10.17
	8	36.32	9.26	42.29	6.63	39.20	8.59
	10	43.53	6.87	40.76	10.82	42.22	9.00
	12	46.65	7.98	46.64	7.50	46.64	7.67

a. Total score possible.

Table IV

F-Ratios for Grade Trends and for Sex Within Grade Effects for FOI Item Scores

	UNIVARIATE F's (d.f. = 1,269)							= MULTIVARIATE F's (d.f. = 7.263)
	Conservation			Combinatorial Thinking		Propositional Logic		
	Weight	Volume	Density	Comb.	Ho.	Hockey	Rose	
Grade								
Linear	13.02**	20.55**	50.93**	21.81**	14.25**	27.17**	23.30**	12.57**
Quadratic	<1	<1	4.13*	<1	<1	<1	1.71	1.18
Cubic	<1	<1	2.55	<1	<1	1.31	3.16	1.32
Sex Within Grade								
Grade 6	<1	1.44	<1	8.88*	<1	2.75	<1	2.02*
Grade 8	1.97	1.07	3.40	12.02**	<1	5.01*	<1	2.43*
Grade 10	<1	7.32**	1.36	1.40	4.72*	1.29	<1	2.17*
Grade 12	<1	<1	1.15	1.17	2.88	<1	1.03	1.20

* $p \leq .05$

** $p \leq .01$

fell within each 5-point interval between 20 and 54 as well as those at the two extremes (< 20 and > 55) was calculated. These data are presented in Figure 1. It will be noted that the distributions of the two younger groups are somewhat bimodal in nature, with the lower mode for grade 6 students falling in the 25 - 29 score range and that for grade 8 students in the 30 - 34 range. Considering that a score of approximately 32 would represent the borderline between a 50 percent "passing" and "failing" criterion on this 63 point test, then both of these lower modes could be classified as falling within the "failing" range. The second and higher score mode was in the 35 - 39 range for grade 6 students and in the 40 - 44 score range for the grade 8 students. For the older two groups of grade 10 and grade 12 students however, the distributions were clearly unimodal and negatively skewed, with the mode for grade 10 in the 40 - 44 interval and that for grade 12 in the 50 - 54 interval. In addition, if the 30 - 34 interval is taken as representing the boundary between a passing and failing score out of the total of 63 possible, then the commulative precentages indicate that 48 percent of the grade 6 sample received a "failing grade", 33 percent of the grade 8 sample did so, but only 17 percent and 6 percent of grades 10 and 12 respectively did so.

To provide some index of the degree of consistency of individual performance across test items, along with the degree of relationship of individual items with total scores, correlations were computed among these scores. These are presented in Table V. Low but significant correlations between age and item scores were found. In addition, all intercorrelations among test items were significant except for those between weight (a concrete operational conservation task) and three of the formal operational items - hypothesis testing in the chemicals task and the two propositional logic

Figure 1. Distribution of FOI Total Score by Grade

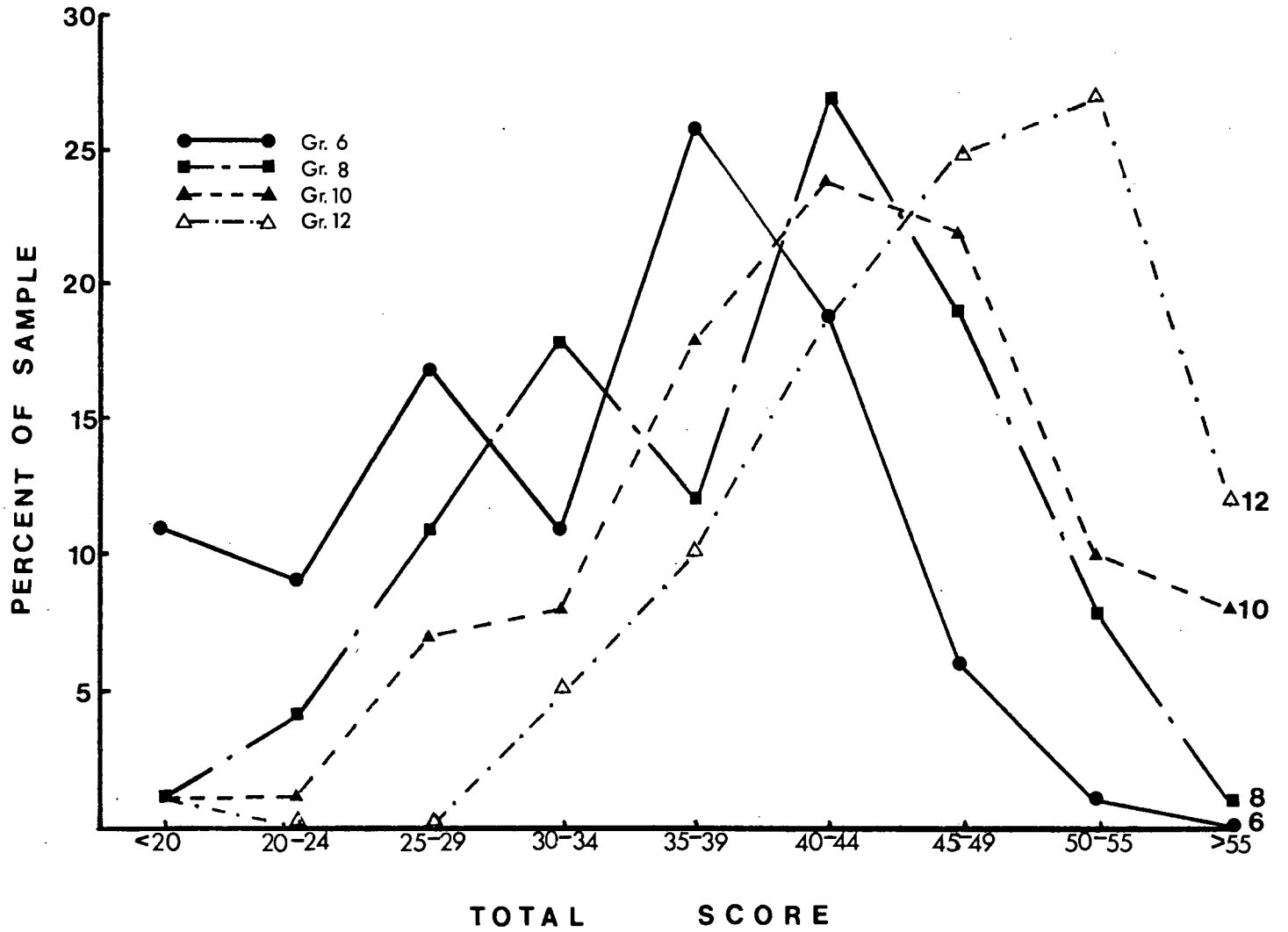
30
25
20
15
10
5
PERCENT OF SAMPLE
Gr. 6
Gr. 8
Gr. 10
Gr. 12
12
10
8
6
<20
20-24
25-29
30-34
35-39
40-44
45-49
50-55
>55
TOTAL SCORE

FIGURE 1

Table V

Product Moment Correlation Coefficients Among FOI Item Scores, Age, and FOI Total Score

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Age (months)	1.0	.19**	.20**	.28**	.21**	.16*	.27**	.25**	.37**
2. Weight Conservation		1.0	.39**	.30**	.20**	.10	.03	.07	.38**
3. Volume Conservation			1.0	.32**	.20**	224**	.19**	.22**	.58**
4. Density Conservation				1.0	.33**	.18**	.17**	.22**	.55**
5. Combinations Generated					1.0	.28**	.24**	.22**	.63**
6. Hypothesis Testing						1.0	.31**	.19**	.57**
7. Propositional Logic (Hockey)							1.0	.54**	.67**
8. Propositional Logic (Rose)								1.0	.65**
9. Total Score									1.0

n = 277

* $p \leq .05$

** $p \leq .01$

problems.

Factor Analysis of FOI

As a means of examining the various FOI item scores for the presence of any underlying structure, these seven scores were subjected to a maximum likelihood factor analysis. The analysis was continued until the eigen values dropped below one. In this case this decision resulted in two factors which together accounted for approximately 53 percent of the total variance (eigen values 1 through 7 were 2.43, 1.28, .87, .80, .63, .56, and .43, respectively). A varimax rotation was then performed, and Table VI presents the resulting factor loadings. Factors I and II appear to correspond to some division between propositional logic (or lack of it) on the one hand, and conservation on the other, with competencies required by the two aspects of the chemicals task being equally and moderately implicated in the two factors. More specifically, Factor I would appear to involve something more than the concrete operational abilities involved in conservation of weight. Rather, the pattern of factor loadings associated with Factor I suggests the ability to think in a hypothetico-deductive fashion, to generate and test hypotheses (i.e., loading of the hypothesis testing component of the chemicals task), and to carry out such thinking on the basis of verbally stated propositions alone (i.e., loadings associated with the Hockey and Rose problems). In short, it seems appropriate to label Factor I as "propositional logic".

On the other hand, Factor II seems most accurately described as the ability to simultaneously coordinate transformations along two or more dimensions as required by the volume and density conservations, and hence to infer proportionality. In addition to this is some ability in combinatorial thinking, as implied by the modest factor loadings of both aspects of the

Table VI

Factor Analysis of FOI Item Scores for 277 Students in Grades 6, 8, 10, and 12 - A Varimax Rotation.

FOI Item	Factor I	Factor II
Weight Conservation	.013	.602
Volume Conservation	-.186	.577
Density Conservation	-.181	.535
Combinations Generated	-.265	.379
Hypothesis Testing	-.333	.253
Propositional Logic (Hockey)	-.865	.052
Propositional Logic (Rose)	-.613	.162
Percent of Total Variance	34.64	18.29

chemicals task in Factor II. In Piagetian terms, the pattern of factor loadings on Factor II could be interpreted as the coordinated application of the INRC group of cognitive operations to the solution of these problems.

On completion of the factor analysis with varimax rotation, two orthogonal factor scores were estimated for each of the 277 individuals, using the Anderson and Rubin (1956) formula. It should be noted that this formula results in factor scores which are orthogonal but not univocal. These estimated scores are standardized with a mean of 50 and a standard deviation of 10. It was these two factor scores, entered into the regression equation sequentially in the order of Factor I and Factor II which served as covariates in the subsequent analysis of the memory performance data.

Paired Associate Performance

Data Analysis: The mean number of correct responses are presented in Table VII as a function of grade (4), treatment mode (3), trials (3), and item type (4). The first two factors are between-subjects while the remaining two factors represent within-subject repeated measures. Multivariate analysis of variance was performed on the data to examine trends across grade levels, the effects of treatment within grade, and sex within treatment within grade. As the questions of major interest in this research involved grade and treatment effects within the two abstractness levels, twelve new dependent variables were created from the original item type by trials variates. The first, the sum of the original six concrete variates was created to examine the total between-subjects effects for concrete pairs. Five additional concrete item type variates were orthogonal transformations of the original six concrete variates and were created to represent the within-subjects effects of trials: (1) M trial 1 - M(trial 2 + trial 3); (2) M trial 2 - M trial 3; meaningfulness (high m - low m); and

Table VII

Mean Recall by Grade, Treatment, Trials, and Item Type

	Trial 1				Trial 2				Trial 3			
	CL	CH	AL	AH	CL	CH	AL	AH	CL	CH	AL	AH
Grade 6												
Control	1.83	1.50	.83	1.25	3.33	2.67	1.25	2.42	3.58	3.33	2.67	3.42
Repetition	1.17	.83	.42	1.50	2.42	2.17	1.33	2.75	3.17	2.58	2.33	3.33
Trained	3.17	3.25	.83	2.75	3.92	3.92	1.92	3.67	4.00	3.83	2.58	4.00
Overall	2.06	1.86	.69	1.83	3.22	2.92	1.50	2.94	3.58	3.25	2.53	3.58
Grade 8												
Control	1.67	1.92	.75	1.92	3.42	2.92	2.08	3.33	3.67	3.33	3.08	3.75
Repetition	2.67	1.83	.92	1.67	3.67	3.25	1.75	3.17	3.92	3.67	2.92	3.92
Trained	2.50	2.75	1.08	2.83	3.67	3.33	2.08	3.67	3.67	3.75	2.92	3.83
Overall	2.28	2.17	.92	2.14	3.61	3.17	1.97	3.39	3.75	3.58	2.97	3.83
Grade 10												
Control	2.42	2.75	1.00	2.08	3.67	3.58	2.25	3.50	3.83	3.83	2.83	3.92
Repetition	2.17	1.50	.75	1.67	3.42	2.67	1.75	2.83	3.75	3.50	2.92	3.83
Trained	3.33	2.75	1.33	3.00	4.00	3.67	2.50	3.67	4.00	3.92	3.08	4.00
Overall	2.64	2.33	1.03	2.25	3.69	3.31	2.17	3.33	3.86	3.75	2.94	3.92
Grade 12												
Control	3.08	2.75	1.50	3.00	3.75	3.67	2.75	3.67	4.00	3.92	3.42	3.83
Repetition	1.67	1.67	1.33	2.33	3.08	2.75	2.25	3.33	3.92	3.58	3.08	3.83
Trained	3.75	3.67	1.17	3.58	4.00	4.00	2.25	3.92	4.00	4.00	3.50	4.00
Overall	2.83	2.69	1.33	2.97	3.61	3.47	2.42	3.64	3.97	3.83	3.33	3.89

the trials by m interactions. The same six new variates were created to represent these effects within abstract pairs as well. After the multivariate tests were performed considering all 12 variates simultaneously, univariate tests were performed on each of the 12 variates separately.

Trend analyses were performed to examine the influence of grade on recall. The effects associated with grade were partitioned into three orthogonal components: linear, quadratic, and cubic. The effect of treatment within grade was examined using two non-orthogonal contrasts, in the following order of testing:

$$\hat{\Psi}_1 = \underline{M} \text{ Repetition} - \underline{M} \text{ Trained}$$

$$\hat{\Psi}_2 = \underline{M} \text{ Control} - \underline{M} \text{ Trained}$$

As these contrasts are non-orthogonal and differ from those used by Rohwer (i.e. $\hat{\Psi}_1 = \underline{M}C - \underline{M}T$; $\hat{\Psi}_2 = \underline{M}C - \underline{M}R$), a word of explanation is warranted to justify their selection for the present research. First, none of the three possible orthogonal sets of contrasts made theoretical sense in testing the elaboration hypothesis at all grade levels as elaboration is operationally defined as control group performance equivalent to the trained group which has in turn been found to be superior in performance to the repetition group.

Secondly, given that one must use a non-orthogonal pair of contrasts, the order in which the contrasts are tested becomes of critical importance, since the sum of the separate sums of squares for each term in the model exceeds the total sums of squares (i.e., there would be "double-counting" of share variance among non-orthogonal contrasts). In this case, the contrast tested second will be treated as if it were one half of an orthogonal pair of contrasts, while the first tested contrast will be given a more 'liberal' test and will be more subject to Type I errors of false rejection

of the null hypothesis. The issue then becomes one of determining on which contrast one is least willing to make a Type I error. After careful consideration of the consequences of errors, it was decided that while the risk of falsely infering the performance of the trained group to be different from that of the repetition group would be bothersome, it would be of less theoretical consequence than making a similar error of judgement concerning the comparison of the control and trained groups. This decision seemed further justified in light of the numerous studies which have found the type of training employed in this research to be facilitative, thus making the MR vs MT contrast less open to the need for a critical test.

Finally, it should be noted that once the decision was made to use the MC vs MT as the second contrast, the difference between the other contrast which is to be entered first becomes one of name alone. That is, the same numerical value results whether it is called MR vs MT as was done here, or whether one refers to this other contrast as MC vs MR as Rohwer chooses to refer to his contrast which he uses with the critical MC vs MT one.

Following the analysis of variance described above, the analysis of covariance of recall scores was performed using as covariates each individual's two factor scores generated from the factor analysis of the FOI scores. In this manner, the influence of logical thinking abilities (as measured by the FOI) on memory performance could be assessed by comparing the results of the two analyses.

Grade

Both the test of linearity for within-concrete ($F(1,120) = 18.75$, $p \ll .01$) and within-abstract effects ($F(1,120) = 23.20$, $p < .01$) were highly significant. For the eight concrete pairs mean recall for grades 6, 8, 10, and 12 was 5.63, 6.19, 6.53, and 6.81, respectively. For the abstract pairs,

these means were 4.36, 5.07, 5.21, and 5.86, respectively.

When these data were subjected to a covariate analysis, using the two FOI factor scores to statistically control for the influence of formal thinking abilities, both the test of linearity of the within-concrete ($F(1,118) = 4.76$, $p < .05$) and within-abstract effects ($F(1,118) = 7.80$, $p < .01$) remained significant. In Figure 2 the difference between observed and estimated recall by grade based on the covariate model with two covariates can be seen. It will be noted that the difference between observed and estimated recall is greatest at the two extremes of the grade range with very little difference at the grade 8 level. With the influence of logical thinking abilities partialled out, observed recall of concrete and abstract pairs is lower than estimated recall at the grade 6 level. Conversly, for grade 10 and 12 students observed recall is higher than that which would be estimated if logical thinking abilities are used as covariates.

To examine the degree to which these results were consistent across trials and levels of meaningfulness, an additional analysis of the grade trends was performed on the original 12 dependent variables. The univariate F's associated with the linear component were all highly significant for the 12 measures, while none of the tests associated with either the quadratic of cubic components reached statistical significance. When the covariate analyses were performed, only three univariate F's associated with the linear component remained significant, however. These were for CH pairs on trial 3 ($F(1,117) = 5.75$, $p < .05$), and for AH pairs on trial 1 ($F(1,117) = 11.87$, $p < .01$) and trial 3 ($F(1,117) = 3.85$, $p < .05$). Again, none of the tests associated with the remaining two trends were statistically significant.

In summary, a strong linear trend across grades was found for both

Figure 2. Differences Between Observed and Estimated Item Recall Based on Covariate Model, by Grade and Item Concreteness

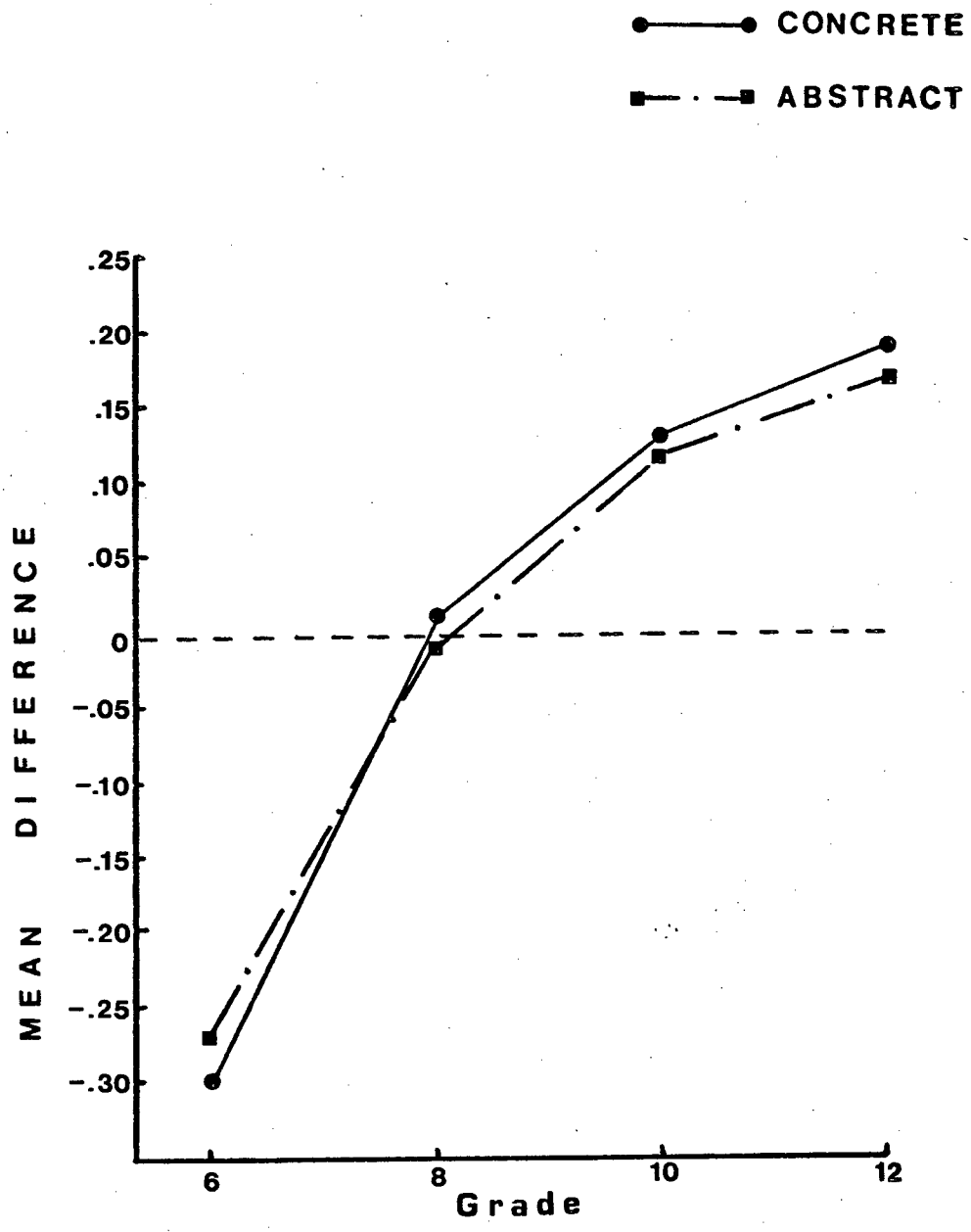
CONCRETE
ABSTRACT
.25
.20
.15
.10
.05
0
-.05
-.10
-.15
-.20
-.25
-.30
MEAN DIFFERENCE
6
8
10
12
Grade

FIGURE 2

concrete and abstract pairs, with recall performance improving with grade. The results of the analysis on the original 12 scores also indicated that this linear trend was consistent across trials and levels of m. When the variance associated with logical thinking abilities was partitioned out, the tests of the linear component associated with the within-concrete and within-abstract effects still reached statistical significance. From the results of the covariate analysis on the original scores, this pattern was found to be related to CH pairs on trial 3, and to AH pairs on trials 1 and 3.

Treatment Within Grade: ($\hat{\Psi}_1$ = MR - MT; $\hat{\Psi}_2$ = MC - MT)

A summary of the tests for the treatment within grade comparisons are presented in Table VIII. Spontaneous elaboration of either concrete of abstract pairs was inferred within a grade level if performance of the control group did not differ from that of the trained group ($\hat{\Psi}_2$ = C-T) with the provision that performance of the trained group would be superior to that of the repetition group ($\hat{\Psi}_2$ = R-T).

Grade 6: From Table VIII it is evident that at this grade level the test of the first contrast, R-T was significant for concrete pairs (MR = 4.11, MT = 7.36) but not for abstract ones (MR = 3.89, MT = 5.25). The tests also indicated that this superiority of trained over repetition group performance for concrete pairs was consistent across levels of m but varied from trial 2 to trial 3. From Figure 3 it is apparent that this difference was greater on trial 2 than on trial 3. No such interactions were suggested by the univariate tests of abstract noun pairs.

The tests of the second comparison, C-T were concrete pairs (MC = 5.41, MT = 7.36) as well as for abstract pairs (MC = 3.95, MT = 5.25). In addition, the univariate tests for concrete pairs indicate that while this

Table VIII

F-Ratios for Treatment Comparisons Within Grades

	Univariate F's (d.f. = 1,120)											
	Concrete Noun Pairs						Abstract Noun Pairs					
	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3
Grade 6												
MR - MT	28.86**	2.55	4.15*	<1	<1	2.27	2.40	<1	<1	<1	<1	<1
MC - MT	15.77**	6.95**	5.21*	1.55	<1	2.76	6.12**	<1	7.98**	6.72**	2.54	<1
Grade 8												
MR - MT	<1	<1	<1	2.53	6.60**	<1	<1	<1	2.66	<1	2.92	<1
MC - MT	3.51	3.02	<1	<1	<1	<1	<1	5.00*	<1	1.21	<1	<1
Grade 10												
MR - MT	9.28**	3.18	5.74*	2.53	<1	1.20	4.27*	1.43	7.74**	<1	<1	<1
MC - MT	1.16	<1	<1	1.77	2.91	<1	1.60	3.03	<1	<1	1.66	<1
Grade 12												
MR - MT	19.55**	14.34**	16.59**	<1	1.72	<1	2.40	<1	<1	<1	4.42*	1.45
MC - MT	2.35	3.72	1.55	<1	<1	<1	<1	<1	<1	2.72	<1	1.93

* $p \leq .05$

** $p \leq .01$

Note. R = Repetition, T = Trained, C = Control, T1 = Trial 1, T2 = Trial 2, T3 = Trial 3, T23 = M(T2 + T3), m = low m - high m.

Figure 3. Mean Item Recall by Grade, Treatment Group, Trials, and Item Concreteness

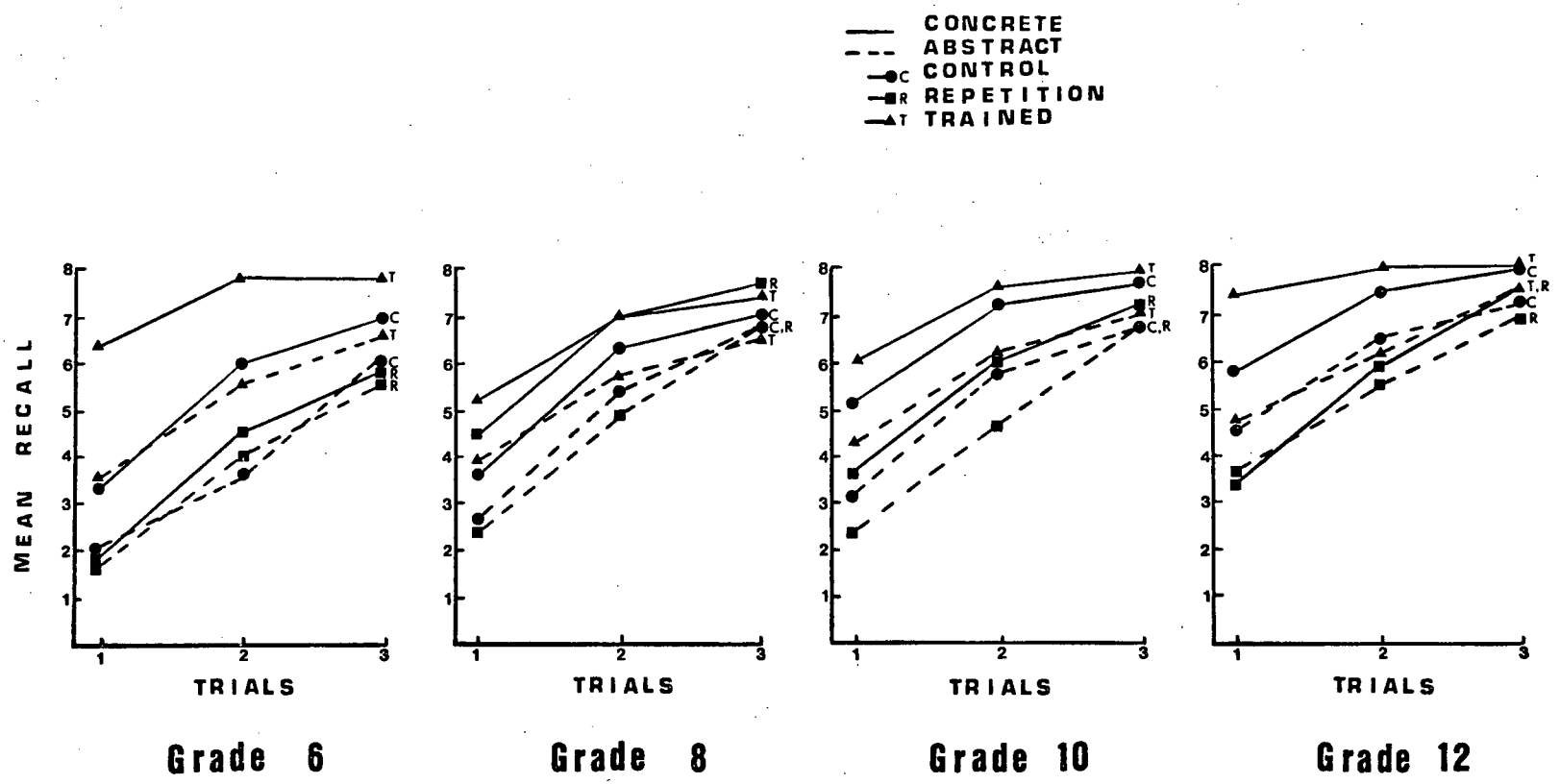
CONCRETE
ABSTRACT
C CONTROL
R REPETITION
T TRAINED
MEAN RECALL
TRIALS
Grade 6
Grade 8
Grade 10
Grade 12

FIGURE 3

result did not interact with level of m, significant interactions were found with trials. From Figure 3 it would appear that the difference between the control and trained groups was greater on trial 1 and trial 2 than on trial 3. For abstract pairs the test of m was significant, and the means indicate that the difference between the two groups was greater for AH pairs (MC = 2.36; MT = 3.47) than for AL pairs (MC = 1.58, MT = 1.78). In addition the difference between control and trained group performance also varied from trial 2 to trial 3, and Figure 3 indicates that this difference was greater on trial 2 than on trial 3.

In summary, evidence was not obtained for spontaneous elaboration of abstract nouns over the three trials or for concrete nouns on the first two trials. The interaction of performance with trials for the C-T comparison does suggest that the control group may have been spontaneously elaborating by trial 3 although the R-T difference on this trial was no longer as large as on previous trials. Further, the results indicate that training promoted superior performance when compared to repetition instructions for concrete pairs, but not for abstract pairs.

Grade 8: As the results of Table VIII indicate, one test of the R-T contrast was significant. This was the interaction between level of m and the first trials effect (T1 - T23) for concrete pairs. An examination of the means for this rather complex interaction suggests the following. Among the CL pairs performance of the repetition group was slightly higher than trained, and this pattern was consistent on all trials (T1: MR = 2.67, MT = 2.50, T23: MR = 3.84, MT = 3.67). For CH pairs, however, the performance of the trained group was higher than that of the repetition group, and this difference was much greater on trial 1 than on the average of the other two trials (T1: MR = 1.83, MT = 2.75; T23: MR = 3.46, MT = 3.54).

For the tests of the C-T contrast, only that associated with the first trials effect for abstract pairs was significant. The means indicate that the difference between control and trained group performance was greater on trial 1 (MC = 2.67, MT = 3.91) than on the average of the other two trials (MC = 6.12, MT = 6.25).

In summary, there was insufficient evidence to infer spontaneous elaboration among grade 8 students due to the lack of significant difference between the trained and repetition groups' performances. This pattern did not interact in a systematic way with trials or levels of m.

Grade 10: For students at this grade level the tests of the R-T comparison for concrete and for abstract pairs were significant. The means indicate that the trained group exceeded the repetition group for both concrete (MR = 5.67, MT = 7.33) and abstract pairs (MR = 4.58, MT = 5.86). It will further be noted that this result interacted with trials for both concrete and abstract pairs when trials 2 and 3 were compared. From Figure 3 it can be seen that this R-T difference was greater on trial 2 than on trial 3 for both levels of abstractness.

For the second comparison, C-T, none of the univariate tests were statistically significant, indicating that control and trained instructions produced similar levels of recall at this grade level.

In summary, the univariate tests support the conclusion that grade 10 students were spontaneously elaborating both concrete and abstract pairs from the onset of trial 1, but that the difference between repetition and trained group performance was smaller on trial 3 than on the previous two trials. This pattern of results did not vary with level of m.

Grade 12: For students at this grade level, the test of the R-T comparison was significant for the within-concrete effect, with means of 5.56

for repetition and 7.81 for trained subjects. The within-abstract test was not significant, however, with means of 5.38 for repetition subjects and 6.11 for trained. It will also be noted from Table VIII that both of the tests of the trials effects with concrete were significant. From Figure 3 it can be seen that the difference between the groups decreased markedly with each trial as the repetition group gradually approached the high level of performance of the trained group with these concrete pairs. For abstract pairs the test of the interaction between m and the first trials effect (T1 - T23) was also significant. An examination of the means of this interaction suggests that for AL pairs on trial 1 the performance of the repetition group was greater than that of the trained group, but this pattern was reversed on the remaining two trials (T1: MR = 1.33, MT = 1.17; T23: MR = 2.67, MT = 2.88). For AH pairs, trained group performance was consistently greater over trials, but the difference was larger on trial 1 than on the remaining two trials (T1: MR = 2.33, MT = 3.58; T23: MR = 3.58, MT = 3.96).

For the second comparison, C-T, none of the tests approached significance, indicating the control and trained groups' performance did not differ significantly.

In summary, evidence of spontaneous elaboration was found for concrete pairs from the onset of trial 1. The same cannot be said for abstract pairs as the R-T contrast did not reach significance. The results shown in Figure 3 would suggest that this was due to the relatively high level of performance of the repetition group, rather than to low performance levels of the trained group. This pattern of results did not vary systematically with level of m.

Treatment Within Grades - Covariate Analysis

As these comparisons were all performed within grade levels, it was not to be expected that the results would change to any significant extent when the influence of logical thinking abilities was partialled out. This lack of change was further anticipated, given the fact that subjects within each grade level were assigned to treatment conditions by using the FOI total scores as a matching variable. Thus, the results of the covariate analyses could be seen as a double-check on the efficiency of this matching procedure. When the results presented in Table VIII were compared with these analyses of covariance, it was readily apparent that none of the tests of effects had changed significantly. A detailed report of these results can be found in Appendix E.

In summary, the results of the treatment comparisons within grades indicated that grade 10 and 12 students were spontaneously elaborating concrete pairs from the onset of trial 1. There was some suggestion that grade 6 students were spontaneously elaborating by trial 3, but no such pattern could be inferred from the results for grade 8 students with the concrete pairs. For abstract pairs only grade 10 students would seem to warrant that conclusion as well. No evidence of elaboration was found for grade 6 and 8 students with these abstract pairs. Further, no systematic influence of level of meaningfulness was found in these results. For grade 6 students it was found that level of m among the abstract pairs significantly influenced the degree to which training promoted recall, relative to the repetition group.

Grade Trends Within Treatment Conditions

To examine further differences in response to the treatment conditions as a function of grade level and logical thinking abilities, two further

analyses were performed. Performance was assessed by examining the data for significant linear, quadratic, or cubic grade trends within each treatment condition first without and then with the two FOI factor scores treated as covariates. A summary of the results of these analyses are presented in Table IX. (It should be noted that the same 12 dependent variates as reported in Table VIII were employed in these analyses, but as the only variates of central interest were the within-concrete and within-abstract effects, only these are reported here. A full report of the results for all 12 variables is provided in Appendix E.)

The results of the analyses clearly indicate a significant linear trend for control group subjects with both concrete and abstract pairs. For repetition group performance, the results are less straightforward. All three components are significant for concrete pairs. From Figure 4 the most accurate description of the trend over grades for the repetition groups with concrete pairs appears to be quadratic, while that for abstract pairs is linear. The quadratic grade trend for concrete pairs is the result of unusually high performance among grade 8 repetition subjects. Finally, for the trained group, there is evidence of a quadratic grade trend for concrete pairs, primarily as a result of the low level of performance of the trained grade 8 students. None of the tests of the effect of m within either concrete or abstract pairs were significant.

The result changed very little when variance accounted for by formal operational abilities were partialled out statistically. The univariate tests of the linear component for both the within-concrete and the within-abstract effects remained statistically significant. In addition, the quadratic trend for concrete pairs remained significant for both repetition and trained groups. The linear trend for abstract pairs was no longer

Table IX

F-Ratios for Grade Trends Within Treatment Conditions

	Analysis of Variance		Analysis of Covariance	
	Concrete	Abstract	Concrete	Abstract
CONTROL				
Linear	14.88**	15.44**	7.66**	9.03**
Quadratic	<1	<1	<1	<1
Cubic	<1	<1	1.01	<1
REPETITION				
Linear	5.52*	6.66*	1.42	2.45
Quadratic	11.63**	<1	8.85**	<1
Cubic	5.19*	11556	5.00*	1.42
TRAINED				
Linear	1.67	3.35	<1	<1
Quadratic	4.02*	≤1	5.21*	<1
Cubic	1.01	<1	1.13	<1

**p ≤ .01

* p ≤ .05

Figure 4. Grade Trends Within Treatment Conditions

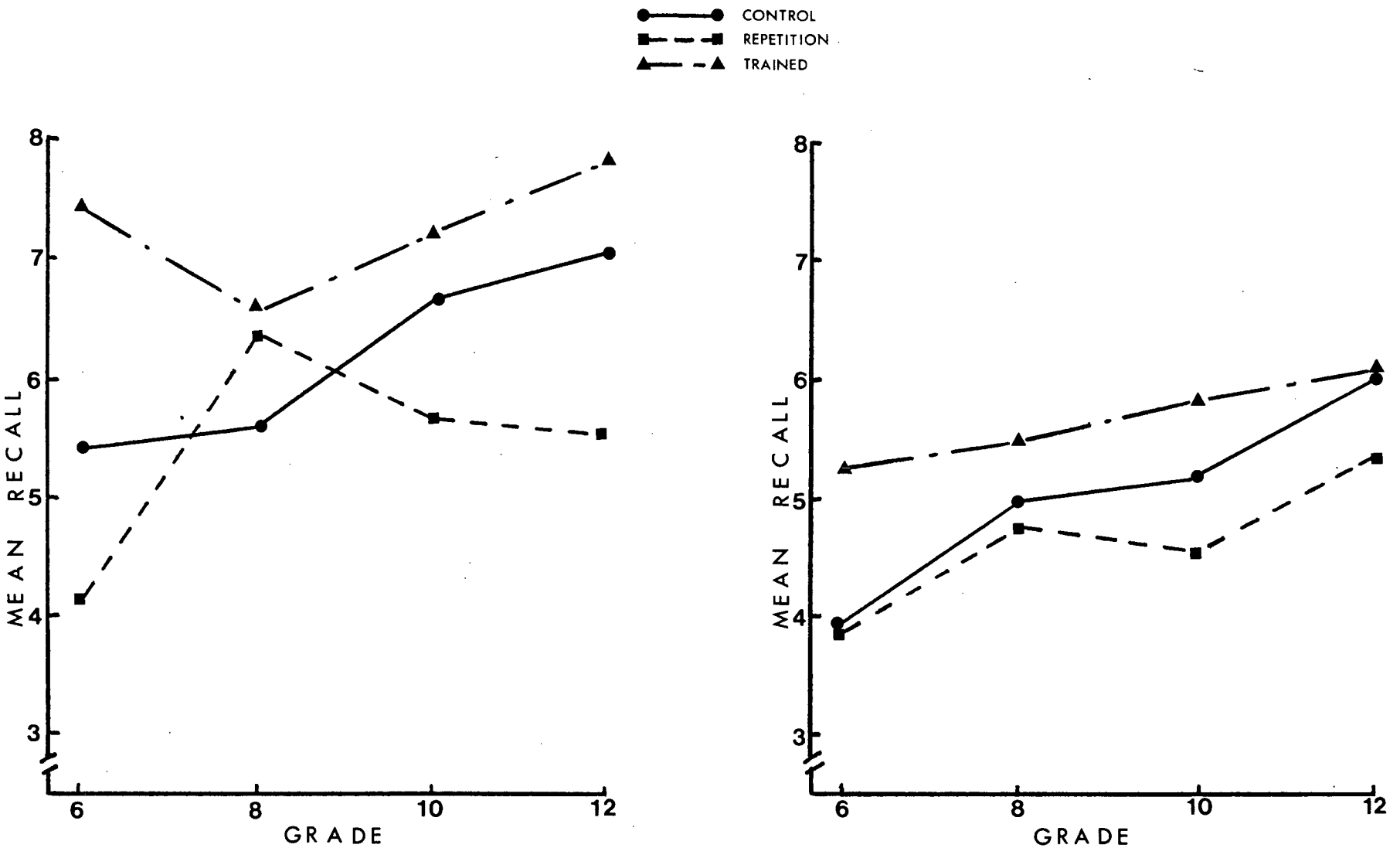
CONTROL
REPETITION
TRAINED
MEAN RECALL
8
7
6
5
4
3
6
8
10
12
GRADE
CONCRETE
MEAN RECALL
8
7
6
5
4
3
6
8
10
12
GRADE
ABSTRACT

FIGURE 4

significant for the repetition subjects, however.

In summary, control group performance was characterized by a linear increase in recall with grade over both concrete and abstract pairs. When logical thinking abilities were used as covariates, the linear trend remained significant. Among repetition groups, performance on concrete pairs was quadratic in trend due to the high performance of grade 8 students. For abstract pairs a linear increase in recall was found. Only the quadratic trend with concrete pairs persisted in the covariate analysis, however. For trained subjects there was evidence of a quadratic trend with concrete pairs in both analyses, again due to performance of the grade 8 students.

A Further Note on Formal Operational Abilities

The results reported thus far for overall grade trends and for grade trends within treatment conditions indicate that logical thinking abilities, as assessed by the FOI account for very little of the age-related variance in memory performance. A further test of this relationship was performed by regressing the two combined FOI factor scores onto the 12 dependent variates listed in Table VIII. A significant amount of the variance in recall of concrete pairs was accounted for by the FOI scores (Multi R^2 = .0622; $F(2,118) = 3.92$, $p < .05$), although with abstract pairs the test only approached significance (Multi R^2 = .0422; $F(2,118) = 2.60$, $p = .07$). The effect of level of meaningfulness within the abstract pairs was significant, however (Multi R^2 = .0538; $F(2,118) = 3.35$, $p < .05$). When the observed and predicted estimates of this effect were examined, it became apparent that logical thinking abilities accounted for a greater amount of the variance in low m abstract pairs than in high m abstract pairs.

While the information regarding the overall relationship between logical thinking and recall is of general interest, a much more pertinent

question concerns the degree to which these formal operational skills interact differentially with recall in the three groups. The preceeding analyses of variance and covariance of grade trends within treatment groups provide relevant information, but do not constitute a direct test of this type of aptitude-treatment interaction. To examine the data for presence of significant interactions, a parallelism test was performed which examined the slope of the regression lines of the four dependent variables (recall of the CL, CH, AL, and AH pairs) onto the combined covariates for any evidence of nonparallelism across the 24 cells of the design (sex within treatment within grade). None of the four separate F-tests was statistically significant (CL: $F(46,72) = 1.42$, $p = .09$; CH: $F = 1.28$, $p = .17$; AL: $F = 1.05$, $p = .42$; AH: $F < 1$). The multivariate F-test of parallelism of the regression hyperplanes was also not statistically significant ($F(184,278) = 1.22$, $p = .06$), indicating that logical thinking abilities do not predict memory performance differentially among the 24 different groups.

As a further examination of this lack of any systematic difference of the influence of logical thinking by treatment condition, the parallelism test was followed up with stepwise regression analyses, treating each of the two FOI factor scores as separate predictors of recall of the four pair types within each treatment condition. These analyses are summarized in Table X. It is first apparent from these data that only a small percent of total variance in recall performance is accounted for by either of the FOI scores. In addition, neither one of the two factor scores is uniquely a more powerful predictor of this performance. If any measure of differential predictive power as a function of treatment groups could be inferred, it would be that Factor I is a somewhat more powerful predictor of control and repetition group performance. Among the group of most interest, the

Table X

Regression Coefficients and Associated F-Ratios for Regression Analyses Between FOI Factor Scores and Recall Scores

	FACTOR I			FACTOR II		
	Reg. Coef.	F(1,46)	% Total Variance	Reg. Coef.	F(1,46)	% Total Variance
Control						
CL	-.05	2.68	6	.06	1.71	4
CH	-.07	3.39	7	.05	<1	2
AL	-.05	1.76	4	.08	2.81	6
AH	-.07	4.25*	8	.05	1.20	3
Repetition						
CL	-.07	4.25*	9	.07	2.87	6
CH	-.05	1.54	3	.05	<1	2
AL	-.04	<1	2	.09	4.25*	8
AH	-.07	4.72*	9	-.03	<1	1
Trained						
CL	-.01	<1	1	.04	4.27*	9
CH	-.04	2.20	5	.04	1.66	3
AL	-.06	2.04	4	.07	2.70	6
AH	.01	<1	1	.04	3.54	7

* $p < .05$

control subjects, the only relationship which reached statistical significance was between Factor I scores and recall of AH pairs.

In summary, logical thinking abilities as assessed by the FOI account for very little age-related variance in memory performance as indicated by the analyses of overall grade trends, grade trends within treatment groups, and overall regression analysis. This influence does not vary systematically over treatment conditions to produce significant aptitude-treatment interactions.

Level of Abstractness The results of the previously reported treatment within grades analyses permit some general statements to be made regarding age differences in spontaneous elaboration of concrete and abstract nouns. Because of the dependency between associative meaningfulness and abstractness of the material however, these results can not be inferred to offer a direct test of the influence of level of abstactness on memory performance. It should be recalled that the construction of the p-a list was such that a test could be made by comparing CL and AH performance due to the fact that these two pair types did not differ in rated m within grades. The results of an analysis on the original 12 recall scores presented in Table XI provide information relevant to the comparison of CL and AH performance. For grade 6 students it will be noted that the R-T contrast was not significant for AH pairs until trial 3 but was significant for the CL pairs from the first trial. The difference between control and trained group performance was significant for both pair types on all trials with one exception - CL recall on trial 2 (a result that would imply spontaneous elaboration). At the grade 8 level comparable results are found for both CL and AH pairs on all trials. For grade 10 students, unlike those in grade 6, training was found to produce recall which is different from that

Table XI

F-Ratios for Treatment Within Grade Comparisons using Original Scores.

	Univariate F's (d.f. = 1, 120)											
	Trial 1				Trial 2				Trial 3			
	CL	CH	AL	AH	CL	CH	AL	AH	CL	CH	AL	AH
Grade 6												
MR - MT	13.01**	12.77**	1.70	1.58	20.56**	11.16**	< 1	< 1	12.64*	20.65**	< 1	4.50*
MC - MT	9.76**	12.34**	< 1	10.65**	3.59	10.34**	2.11	12.39**	4.21*	3.87*	< 1	8.17**
Grade 8												
MR - MT	2.49	1.34	< 1	3.17	< 1	< 1	< 1	1.17	2.02	< 1	< 1	< 1
MC - MT	3.81*	2.80	< 1	3.98*	< 1	1.15	< 1	< 1	< 1	2.69	< 1	< 1
Grade 10												
MR - MT	3.67	8.40**	1.70	4.83*	2.45	8.10**	2.48	5.95*	< 1	2.90	< 1	< 1
MC - MT	4.61*	< 1	< 1	3.98*	1.17	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Grade 12												
MR - MT	22.41**	12.77**	< 1	5.79*	8.83**	10.35**	< 1	2.22	< 1	2.90	1.01	< 1
MC - MT	2.44	3.39	< 1	1.61	< 1	< 1	1.19	< 1	< 1	< 1	< 1	< 1

* $p \leq .05$

** $p \leq .01$

of the repetition group for AH but not for CL pairs. The results of the treatment within grades analysis of concrete pairs would suggest, however that this is due primarily to the fact that repetition instructions do not effectively inhibit all elaborative activity among older subjects. For grade 12 students performance on CL and AH pairs is comparable on trial 1 but the R-T contrast failed to reach statistical significance for AH pairs on trial 2. On trial 3 there are comparable results for the two pair types.

In summary, it would appear that differences in level of abstractness alone are most influential at the younger age level and that the most consistent effect found was that training promoted recall of concrete but not abstract pairs when compared to the repetition group of the same age.

For purposes of further understanding the relationship between abstractness and recall performance (i.e. CL - AH) as well as between m within concreteness levels and recall (i.e. CH - CL and AH - AL), the differences between the mean recall of each of these pair types were computed and are presented in Figure 5 for each treatment group. It is first very apparant that differences in m within abstract pairs consistently produced the greatest difference in recall regardless of grade level or treatment condition. Within concrete pairs only small differences between CL and CH pairs were found, the largest being approximately one half of one item in mean recall of grade 6 control subjects and grades 6, 8, and 10 repetition subjects. Interestingly, the difference was in favor of the lower m CL pairs. For the CL - AH difference, very little difference in recall levels was found among either trained or control subjects as a function of level abstractness. The one possible exception is grade 6 control subjects whose mean recall of CL pairs was approximately one half item higher than with AH pairs. For the repetition group, the influence of abstractness was less

Figure 5. Difference in Mean Recall by Grade as a Function of Level of Abstractness (CL-AH) and Level of Meaningfulness Within Level of Abstractness (CH-CL, AH-AL)

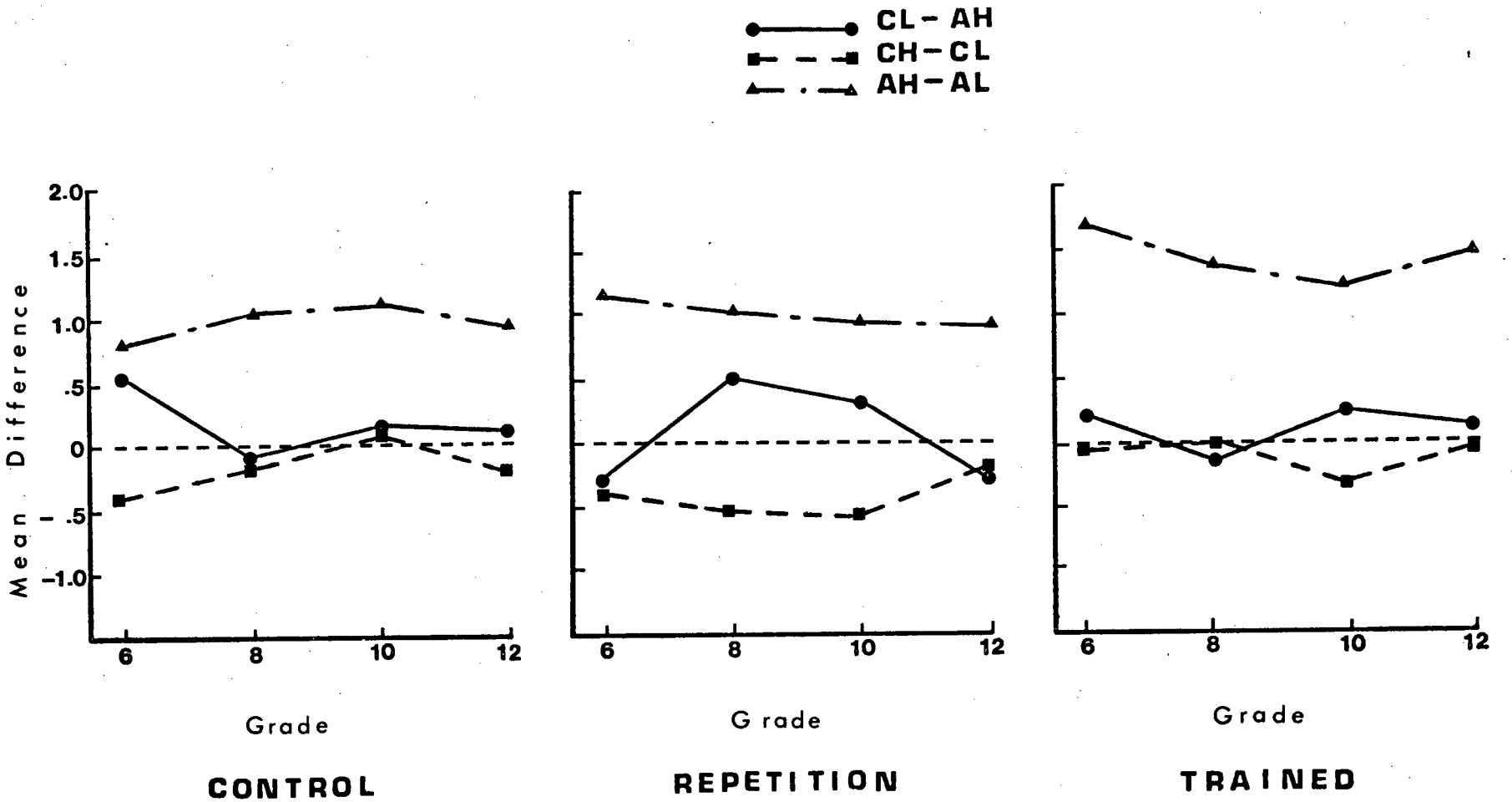
CL - AH
CH - CL
AH - AL
Mean Difference
2.0
1.5
1.0
.5
0
- .5
-1.0
6
8
10
12
Grade
CONTROL
REPETITION
TRAINED

FIGURE 5

systematic across grades. Both grade 6 and 12 students recalled more AH pairs while grades 8 and 10 students performed somewhat better under these instructions with CL pairs.

Sex Within Treatment Within Grade

The results of the analysis of sex differences within treatment conditions within grades are summarized in Table XII. For concrete pairs this test of sex differences was significant for five groups, and in all five cases the recall of females was superior to that of males. These groups were: Grade 6 Repetition MM = 3.22, MF = 5.00; Grade 8 Trained MM = 5.56, MF = 7.56; Grade 10 Control MM = 5.89, MF = 7.50; Grade 12 Repetition MM = 4.78, MF = 6.33. It will be noted from Table XII that these results did not interact with level of m, but in three cases (Grade 8 Control, Grade 10 Control, Grade 12 Repetition) did vary as a function of trials. The m by trials interactions were also found to be significant for grade 8 controls and for Grade 8 and 10 repetition groups. The relevant means are reported in detail in Appendix E.

For the recall of abstract pairs females again significantly exceeded males in several groups. These were grade 8 trained subjects (MM = 4.61, MF = 6.33) and grade 10 controls (MM = 4.11, MF = 6.34). None of the tests of the influence of trials or m were significant but within grade 6 and grade 10 controls the tests of the m by (T1 - T23) interaction were significant. Again, the relevant means can be found in Appendix E.

Interview Information

Following completion of the memory task subjects were requested to complete several activities during an interview. The first of these was sorting the item pairs into two categories; those perceived as "hard" and those perceived as "easier" to remember. These data were recorded for each

Table XII

F-Ratios for Sex Comparisons Within Treatment Conditions Within Grades

		Univariate F's (d.f. = 1, 120)											
		Concrete Noun Pairs						Abstract Noun Pairs					
		Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3
Grade 6	C	<1	<1	<1	1.91	<1	<1	<1	<1	1.38	<1	5.07*	1.51
	R	6.59**	1.62	1.38	<1	<1	<1	1.09	<1	<1	<1	<1	<1
	T	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.95	<1
Grade 8	C	8.81**	1.62	5.51*	1.91	1.15	4.05*	2.93	1.66	<1	<1	3.33	2.95
	R	3.41	<1	2.15	<1	9.49**	<1	1.42	2.32	<1	<1	<1	2.95
	T	8.34**	3.65	<1	<1	<1	1.01	5.33*	<1	<1	<1	3.73	<1
Grade 10	C	5.41*	11.33**	<1	<1	<1	1.01	8.43**	<1	3.53	<1	10.35**	<1
	R	<1	<1	<1	1.01	<1	4.05*	<1	<1	<1	<1	<1	<1
	T	<1	<1	<1	<1	<1	1.01	<1	1.66	1.38	1.49	1.39	1.51
Grade 12	C	<1	<1	<1	<1	<1	1.80	<1	1.37	<1	<1	2.25	<1
	R	5.05*	<1	5.51*	2.27	<1	1.80	3.75	<1	1.99	<1	<1	2.17
	T	<1	1.62	<1	<1	<1	<1	<1	<1	<1	2.09	<1	<1

Note. R = Repetition, C = Control, T = Trained

* $p \leq .05$

** $p \leq .01$

pair, and then summed across the 12 subjects within each treatment group. When the resulting value (number of times a pair was identified as difficult to remember) was correlated with the number of times the item was not recalled by group members over three trials, the resulting r's were uniformly high and positive, ranging from +.84 to +.97 for all 12 treatment groupings. It would appear that all subjects regardless of grade or instructions given, were equally accurate in assessing relative item difficulty on the basis of previous recall performance.

In order to examine the relationship between perceived and actual item difficulty as a function of item type, the results were summed across the four pairs within each item type and then these values were translated into percentage values (see Table XIII). Several trends are apparent from this data. First, the relationship between perceived and actual recall difficulty was consistent across all item types, treatment groups, and grades. It will be noted however, that the perceived difficulty of the AL pairs tended to be disproportionately larger in relation to actual recall performance than any of the other three pair types.

Secondly, concrete pairs of the two m levels tended to be reported as difficult to remember by approximately the same percentage of subjects (with slightly higher values for CH pairs). Among the abstract pairs, however, AL ones were clearly perceived as more difficult than AH pairs.

Thirdly, CL, CH, and AH pairs learned under repetition instructions were more frequently perceived as difficult than the same pairs learned under control or trained instructions (with the possible exception of grade 8 students). For AL pairs, however, perceived difficulty tended to be lower under repetition instructions than under either control or trained instructions, even though average rate of recall was fairly constant regardless of

Table XIII

Relationship Between Perceived and Actual Item Recall Difficulty by Treatment, Grade, and Item Type

		CL		CH		AL		AH	
		Perceived (%)	Actual (%)	Perceived (%)	Actual (%)	Perceived (%)	Actual (%)	Perceived (%)	Actual (%)
Control	6	25	27	27	37	75	60	31	41
	8	17	26	25	31	85	51	19	25
	10	10	17	10	15	77	49	21	21
	12	10	9	19	13	73	36	19	11
Repetition	6	33	44	42	53	60	66	25	37
	8	4	15	17	27	81	53	21	27
q	10	15	22	23	36	88	55	19	31
	12	31	27	27	35	50	44	17	21
Trained	6	4	8	4	8	75	56	10	13
	8	10	18	15	18	75	63	6	14
	10	6	6	21	14	85	42	21	11
	12	0	99	0	3	94	42	10	3

instuctions for these AL pairs.

The second activity required of subjects was to sort items into categories to indicate strategies used during the memory task to facilitate recall. Four sorting categories were made available: "Repeat", "Image", "Sentence", and "Nothing". The results of these sorts were recorded for each individual and then summed across the 12 subjects within each treatment group. It was first noted that the use of the "Nothing" category was extremely infrequent - 105 out of a possible 2304 times (144 Ss x 16 pairs). Its use was most frequent among subjects in the control groups. In terms of percentage of total possible uses, it was reported 14%, 11%, 9%, and 3% of the time by grades 6, 8, 10, and 12 subjects in control groups respectively. It was never reported as a strategy category by subjects given repetition instructions. Among trained subjects, it was reported 2%, 2%, 11%, and 1% of the time by grades 6, 8, 10, and 12 respectively. For purposes of further analysis, "Nothing" responses were combined with repetition responses to form a general non-elaborative category.

Frequency of usage of each of the three remaining categories were summed across the four pairs within each item type and converted into percent of total possible usage. These data are presented in Figure 6. A number of trends are worthy of note. First, the reported use of elaborative strategies (image and sentence) generally increased with age across all treatment conditions, while use of the non-elaborative strategies (categorized here as repetition) declined. The decrease in use of repetition was most apparant in the control condition and less marked among repetition and trained subjects.

Second, among subjects of all grades who were instructed to restrict themselves to rote repetition of pairs, this strategy was only reported used

Figure 6. Reported Strategy Usage by Treatment Group, Item Type, and Grade

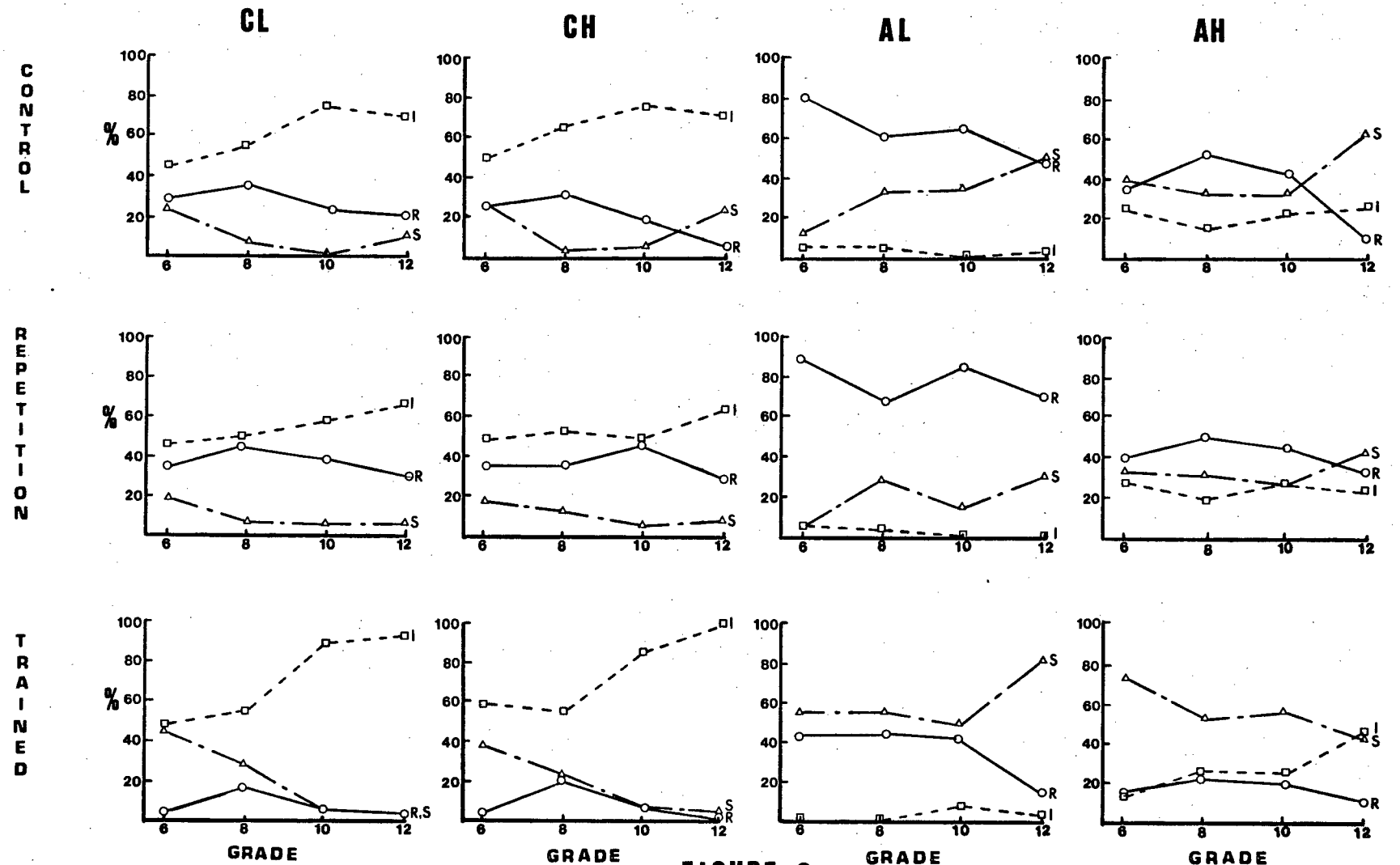
CL
CH
AL
AH
CONTROL
REPETITION
TRAINED
%
100
80
60
40
20
6
8
10
12
GRADE
I
R
S
R,S

FIGURE 6

by greater than 50 per cent of these subjects with the AL pairs. For all other pair types use of imagery and sentence elaboration was reported to a greater extent than repetition.

Thirdly, imagery was clearly the preferred strategy for concrete pairs, regardless of grade of treatment condition, although use of this strategy did increase with age. For abstract pairs repetition was the most frequently reported strategy among control and repetition subjects in the younger three grades, whereas sentence elaboration was the most frequently reported one by trained subjects of all grades and by grade 12 students in all experimental groups. One exception to this for grade 12 students would be noted. For AH pairs the trained grade 12 students used both imagery and sentence elaboration equally.

When all subjects were asked if anyone had ever told them about "ways to make information easier to remember", 55% of the total sample reported having received some instruction. Of this group 38% were given mnemonic instruction by a teacher while the remaining 17% mentioned parents and older siblings as the source of this information. In terms of strategies being recommended by teachers, 61% of those who had received information from this source indicated that some form of rehearsal of rote repetition was the advice being given. The remaining 39% reported being instructed to employ some form of elaborative encoding such as rhyming, imaging, embedding within a meaningful narrative, or "...thinking of some unique meaning that the information has for you" (grade 12 female). Parents and older siblings, if they offered mnemonic advice, were much more likely to suggest use of some form of information elaboration (76%) than rote repetition (24%) unlike teachers. In terms of the total sample of 144 students then, 45% reported never having received advice concerning memorization strategies,

27% had been told to use some form of rote repetition, and 28% had had an elaborative strategy recommended to them.

CHAPTER V

Discussion

Five questions were raised to be specifically addressed by this research. The results presented in the previous chapter and their implications for each of these questions will now be considered one by one.

Spontaneous Elaboration

The first major issue which this research sought to examine concerned the existence of a developmental trend in propensity to spontaneously elaborate during the age period from grade 6 to grade 12, as specified in Question 1. Further, the generalizability of this trend over levels of abstractness and meaningfulness of the materials was also to be considered (Question 2). Information relevant to these questions is available from several sources in the results.

First, it is evident from the overall analysis of grade effects that level of recall performance on a paired associate task does continue to increase in a linear fashion over this age range. This general trend was also found to be consistent across levels of abstractness and meaningfulness of nouns and across three repeated trials. Until performance is considered by treatment groups, however, it is not possible to determine whether this higher level of performance by older adolescents was due to an increased propensity to spontaneously elaborate.

Turning to the second source of relevant information, grade trends within treatment conditions, some further light can be thrown on this issue. It is clear from this analysis that the performance of the unprompted controls did increase in a linear fashion with age, and that this trend held up for both concrete and abstract pairs, regardless of level of meaningfulness. The results of the self-reports of strategy usage by these control

group subjects also confirmed that increasing age was associated with a greater use of elaborative strategies and a decline in use of non-elaborative strategies. In addition, when percent of items correctly recalled was examined for control group subjects by reported strategy usage (non-elaborative versus elaborative strategy for any given pair), recall was consistently higher for those reporting having used elaboration (6%, 9%, 16% and 12% higher recall for grades 6, 8, 10, and 12, respectively), offering some further support for the hypothesis that the rate of recall is related to use of elaborative strategies.

An interesting finding was that performance among repetition group subjects also showed a linear increase with age. When the strategy usage reports were considered a moderate increase in use of elaborative strategies with grade was also found even though overt repetition of pairs was required. Like control group subjects, it was also found that higher percentages of recall (16%, 6%, 6%, and 16% higher for grades 6, 8, 10, and 12, respectively) were given by those reporting use of elaborative versus non-elaborative strategies among these groups. It would appear that propensity to elaborate is a factor of sufficient strength that it becomes extremely difficult to control experimentally once it is part of the subject's memory response repertoire.

Pre-task training in appropriate elaborative strategies proved to be a very effective leveler of performance across grades, as the results of the grade trends within treatment analysis indicated. In keeping with previous evidence of the early development of the 'specific' component of paired associate performance (Rohwer, 1973), it would appear that the operational competence required for prompted elaboration is available at least by the sixth grade. What is lacking in the younger child, and what appeared

not to emerge before the grade 10 level in this research, was an "internal cueing system" which would initiate these elaborative processes spontaneously. A more detailed examination of the issue of training will be discussed when questions 4 and 5 are considered.

Before leaving the results of the grade trends within treatment analyses, one further puzzling outcome should be mentioned. A very strong quadratic trend among the repetition groups was found with concrete pairs, and the data indicated that this was due to unusually high recall at the grade 8 level. In fact, their performance was so high that is was virtually indistinguishable from that of the grade 8 trained students who in turn were lower than the trained group of any grade level. When the self-report data for this grade level was examined for the concrete pairs, there was not an unusually high reported use of elaborative strategies by grade 8 repetition students. However, there was a generally greater use of repetition by all three grade 8 groups with the concrete pairs which could in part account for the low level of trained group performance. Why grade 8 students would be so inclined to use repetition as an encoding strategy is difficult to say. Perhaps they are in some transitional stage as far as the availability of an "internal cueing system" is concerned. They are well aware of the need for some form of action to be taken, but are not yet fully capable of identifying and selecting the mental operations which are most likely to be productive to the task. As a consequence, they are inclined to use the (perhaps) first strategy which they identify in their repertoire, that of rote repetition. By examining the performance of a group trained in both elaborative and nonelaborative strategies and charting the development trends in the selective use of one or the other type, this issue could be examined. Further speculation as to the source of this

pattern of grade 8 results does not seem warranted without this additional research, however.

The third and most critical test of the spontaneous elaboration hypothesis is provided by the treatment comparisons within grades analysis. Positive evidence of spontaneous elaboration of abstract and concrete pairs was found from the onset of trial one for grade 10 students. This pattern was also consistent across both levels of meaningfulness. For grade 12 students, while it was possible to infer spontaneous elaboration for concrete pairs, the statistical evidence did not support this conclusion for abstract pairs. However, visual inspection of the group means in Figure 3, the results of the analysis performed on the original 12 scores, and the evidence of a very high reported usage of elaborative strategies by grade 12 control and repetition students all point to a conclusion that these students were indeed spontaneous elaborators. A ceiling effect in the recall of the three treatment groups within this grade level appears to be the most likely cause for the lack of statistical support for this conclusion.

When performance for concrete pairs was examined across trials, an unexpected effect emerged at the grade 6 level. Although the evidence was not straightforward there was a pattern indicative of spontaneous elaboration on later trials. The results of the analysis on the original 12 scores indicated that this was the case for CL pairs on trial two, but that the effect had "washed out" by trial three. The possibility that this was due to a ceiling effect among the grade 6 trained students who had almost perfect recall on trial two should not be overlooked. However, the self-report data does offer some further support for the contention that at least some grade 6 students were spontaneously elaborating concrete pairs by the end of the third trial.

The evidence, then, suggests that if performance is examined over three trials rather than just one as Rohwer's (Rohwer, et al, 1977) and Pressley's (Pressley & Levin, 1977) research had done, spontaneous elaboration of concrete pairs may be present at the sixth grade level. While one might qualify the degree to which this behavior of sixth grade students can be interpreted as demonstrating an equivalent level of "elaborative propensity" when compared to grade 10 students who elaborate from the onset of trial one, it does suggest that the competency required to be 'active and planfull" may be present at a younger age than earlier research would suggest.

It is particularly interesting that this behavior did not emerge from the onset of the task, and further only emerged with concrete pairs for these grade 6 students. This data can be interpreted as offering some support for a contention made by Case (1974) regarding the development of operational competence. It is his suggestion that if a child has some preliminary form of a structure required by a task, he may consolidate that structure at some point during his encounter with the task, providing that the information processing demands of the task do not overly tax information processing space available to the child at this particular level of development. Translating this concept into terms relevant to the spontaneous elaboration of paired associates, it is evident from the above results that grade 6 students have those mental operations in their repertoire which are necessary for the formation of a semantic relationship between two originally separate entities. This form of elaborative processing in and of itself then must not overly tax the information processing space of the grade 6 child. What is missing initially is the "cognitive executive routine" (Flavell & Wellman, 1976) which will cue these processes. If this routine is to be consolidated during encounter with the task, it will occur with

items which are easy in the sense of ease of forming an elaboration. According to the details of the elaboration hypothesis (Rohwer, 1973) the probability that a semantic relationship will be created is in part dependent upon the variety of meanings which are associated with each member of the pair initially. This greater availability of associative possibilities may represent a sufficiently low level of demand on information processing space that it leaves potential space available for the consolidation over trials of an executive routine responsible for internal cueing. The abstract pairs, on the other hand, because of their lower levels of familiarity and meaningfulness, may fully tax the processing space available just to generate a semantic relationship. Abstract pairs, by their very abstract nature may place an additional demand on information processing space if they require some preliminary processing to 'concretize' them before an elaborative event or episode can be produced by the child, a type of processing referred to by Davidson (1970) as "hypostatization". This demand placed by abstract pairs could be additionally great if a change in strategy was required, a likely outcome if the child was bringing about the semantic coupling by generating interacting images for contrete pairs (as the self-report data would indicate) and then found this a difficult task with more abstract pairs. Had the trials been extended beyond three, it is possible that spontaneous elaboration would eventually generalize to abstract pairs for these grade 6 students as well. This conjecture will have to await the test of further research, however.

Formal Operational Thinking and Spontaneous Elaboration

The third question concerned the strength of the relationship between formal operational abilities and propensity to spontaneously elaborate. It was proposed that the hypotheticodeductive and propositional thinking skills

of this stage of cognitive development may be logically related to and predetermine the availability of the "executive control system" conceptualized as being responsible for the difference between spontaneous and prompted elaborators. The existence of such a relationship was examined by partitioning variance due to logical thinking skills (as assessed by the FOI) and then re-examining recall data for persistence of any developmental trends over grades.

While grade trends were found, the strength of the relationship referred to above was insufficient to account for this pattern in the results. This is not to say that the competencies assessed by the FOI were totally unrelated to recall performance. Regression of the logical thinking scores onto recall scores indicated that a small (6%) but significant amount of variance in recall of concrete pairs was accounted for by the former. For abstract pairs, the regression results indicated a stronger relationship for AH than for AL pairs. Thus, there was some weak evidence of a relationship between these two types of performance when data is collapsed across treatment conditions.

The question of major interest was the degree to which formal operational abilities differentially predicted performance in the three treatment conditions. If the relationships proposed earlier in this report concerning propensity to spontaneously elaborate and the hypothetico-deductive and propositional thinking skills of the formal operational period have any logical validity, than these abilities should be particularly powerful predictors of control group performance but should be less important in determining trained group performance. The results of the covariate analysis of grade trends within treatments failed to support this conjecture. In addi-

tion, the lack of any evidence of a systematic aptitude-treatment interaction between these variables further failed to offer any support for this relationship. From the foregoing, the only justifiable conclusion would seem to be that the abilities assessed by the FOI are related to paired associate performance to some extent, but in a very general manner. No evidence of a case for a unique relationship between these abilities and the "spontaneous" component of paired associate performance has been found.

In attempting to identify the source of variance in elaborative propensity, cognitive developmental indices of a Piagetian form were selected as theoretically representing a potential source. These competencies in hypothesis generation, deductive reasoning and propositional thinking do appear, in theory, to be just the type of skills which would be required of the individual if he/she is to spontaneously adopt the active "strategy-like approach" described by Rohwer. The problem is in the translation of the structural components of Piagetian theory to specific indices which can be used to predict functional processes such as memory performance, a point made earlier in this report. These difficulties are very much akin to those referred to by DiVesta (1973) and others (Cronbach & Snow, 1969; Labouvie-Vief, Levin & Urberg, 1975) as being particularly relevant to aptitude-treatment interaction research, where more often than not the practice has been to employ" ... a shotgun approach in which a large number of aptitude measures are correlated with a minimum of theoretical justification..." (Labouvie-Vief, et al, 1975, p. 558). The alternative approach suggested (DiVesta, 1973) is the generation, apriori, of miniature models which address themselves to the investigation of selected sub-processes, or to the

'microstructure' of performance. This exercise then demands not only that logical analysis of the nature of the potential relationships which may exist be done with considerable specificity, but even more, demands the precise assessment of the trait or aptitude, as well as the structuring of the task such that detailed examination of the component processes can be made. In the present research reference was made earlier to the considerable measurement problems involved, i.e. precision of trait assessment. Specifically, the psychometric issues which have been made apparent in the literature in the assessment of Piagetian formal operational abilities are considerable. Special efforts were made to avoid the most frequent kinds of criticisms which have arisen in this body of research. For example, a cross-section of formal operational tasks requiring both decisions and explanations were used. These were administered and scored according to a standardized procedure. In addition, factor scores rather than raw scores were used in an attempt to have "clean" data less contaminated by random sources of fluctuation. In spite of these efforts there is no assurance that these scores represented anything remotely like 'presence of Piagetian formal operational structures'. Unless this problem of assessment can be resolved, at least to the point where some measure of consensus is reached concerning what tasks and procedures represent an adequate test of these abilities, then the validity of results from research of the type conducted here will continue to be a matter of conjecture.

The second component of the recommendation made by DiVesta (1973), that of the degree to which the structure of the task conditions allowed for specificity of the component processes, this aspect has not been fully resolved in the set of procedures used here for examining spontaneous

elaboration. For example, training or prompting of one group is employed as an experimental manipulation to represent performance as it would be if elaborative strategies are being employed. The results of the self report data indicate, however, that all subjects do not consistently adopt these elaborative strategies; i.e., grade 8 trained performance and performance of all groups with AL pairs. Further, as soon as some flexibility is allowed, as was done in the present trained group in terms of imaginal versus verbal strategies, then one or more additional component processes must be introduced into the task analysis. It was suggested above that there may be a developmental trend with grade in the sub-processes involved in simply selecting an elaborative from a non-elaborative when more than one is prompted. In addition, experimental manipulation of prompts allows for examination of encoding and assumes that once an elaborative event has been formed, it will be equally retrievable by all age levels, given one member of the pair as a cue. The accumulating evidence to suggest that processes involved in retrieval are also subject to developmental variations (Flavell & Wellman, 1976; Salatas & Flavell, 1976) should not be overlooked. In the present research, for example, there were a number of incidences during a recall trial when a child would seem to have some recall of the elaborative event itself, but was unable to retrieve the response term with sufficient specificity (i.e., Grade 6 male, given the pair Desk-Boat: During test trial "Oh, I know that one. The desk has a ....., it's something small on the desk. Oh, what is it? It's something long, something strange for a desk. Oh, I can't quite get it.") If there is some measure of developmental variation in ability to use one member of the pair as a specific retrieval cue for the other member, then the lower level of

performance of the control group subjects would not just be due to failure to spontaneously elaborate at the time of encoding. Unless this retrieval variance can be identified and partitioned out as well, then attempts to identify aptitude-treatment interactions specific to spontaneous elaboration will be unlikely to be successful.

The repetition group cannot be overlooked with regard to the degree to which the structure of the task allows for specificity of component processes. It is once again clear from this research that the repetition instructions, even when required to be performed overtly, do not represent an adequate manipulation to create baseline performance. Inferences concerning spontaneous elaboration hinge on this assumption, a problem which was particularly troublesome in the interpretation of the grade 12 data with abstract pairs. This lack of adequate control over processes would also serve to decrease the likehood of finding significant aptitude-treatment interactions.

One final point of the methodological nature should be made with regard to the formal operations and paired associate performance relationship. The children tested in this research represented a rather restricted sample of the population to begin with. They were very economically advantaged, and were students in schools where achievement levels were higher than provincial norms. This contributed to a rather restricted range of scores on the FOI, particularly after these scores had been subjected to a factor analysis. As in any such measurement situation, this restricted range lessened the probability of finding a significant relationship between this measure and any other measure. The major point to be emphasized is that this may have led to an underestimation of the degree

of the relationship that actually existed between formal operational abilities and recall performance. A replication of the design, using a more diverse subject pool would be required to determine the validity of this contention.

In summary, evidence of a developmental trend in spontaneous elaboration was found, with some suggestion that the onset for concrete pairs is found at the sixth grade level, while abstract pairs are not spontaneously elaborated until the tenth grade. While the results for abstract pairs replicate those found in earlier research (Greer & Suzuki, 1976), the results for concrete pairs suggest that this ability may emerge earlier than previously thought, perhaps due to the use of three repeated trials. This performance did not vary over levels of associative meaningfulness. A very modest relationship would be found between general recall performance and formal operational abilities, but no evidence for these logical abilities being uniquely related to the spontaneous component of elaboration was found. The further investigation of this type of relationship is unlikely to be fruitful, unless more specificity in both the measurement of these logical thinking abilities and in the task analysis of and experimental control of component processes involved in spontaneous elaboration is achieved.

Training

The fourth question concerned the responsiveness of subjects at the various grade levels to training in the use of elaborative strategies of both the imaginal and verbal sort. The results of the R vs T contrast in the treatment within grades analysis provide data relevant to this question.

For concrete pairs training clearly promoted superior recall for students in grades 6, 10, and 12. This superiority of trained students generalized across both levels of associative meaningfulness but interacted with trials. For both grade 6 and 10 students the difference was greater on trial 2 than on trial 3, and for grade 12 students, the difference between R and T was greater on trial 1 than on trial 2, which was in turn greater than that on trial 3. From visual inspection of the data, it was apparent that this dimunition was the result of a ceiling effect for the trained group. Had there been more item pairs, the relative slope of the two lines (see Figure 3) within each grade suggest that the trained group would have maintained its superiority over the three trials for grade 6 students. For the older two groups, and for grade 12 students in particular, the rate of increase over trials for the repetition group would result in no significant difference by a third trial, even with a longer list of concrete pairs.

This pattern of results for repetition groups at the older grade levels in fact serves to reiterate the powerfulness of the propensity to elaborate. It also serves to emphasize the inadequacy of repetition instructions to produce performance representative of a baseline, no-elaboration level. It was hoped that the requirement to repeat overtly would be sufficient to inhibit elaborative processing, and it does seem to have served this purpose on the intitial trial at least. If performance is to be extended over several trials, however some other form of instructions which are engrossing but which will divert efforts away from semantic processing will be necessary. Likely candidates can be found in the research of Craik & Lockhart (1972). For example, having the individual count the

number of vowels on one trial, and then the number of letters with curved versus straight lines may be effective procedures for limiting semantic processing.

Before considering the influence of training on the processing of abstract pairs the grade 8 student performance should be mentioned. There was no indication of facilitation from training at this age level for either pair type. The analysis of sex differences among grade 8 trained subjects did indicate that the performance of the females was significantly higher than males, and that this was the case for both pair types. When these two levels of performance were averaged to represent a group mean for the grade, the resulting value was not different from repetition subjects. Why the grade 8 boys should be less responsive to training than all other subjects is difficult to fathom, and further speculation on the source of this performance seems pointless. It does serve to emphasize again the considerable variability in elaborative skills among individuals within any given age level, however, and suggests the need for an alternative approach than designation of groups by the global variable of grade or age. If future investigations of the elaboration hypothesis are to be fruitful, a preferred experimental approach to the present one might be the use of a within-subjects design. Each subject would be required to learn lists first under control instuctions, then under antagonistic prompting, and finally given explicit or augmented explicit prompts, so that each subject could serve as his own control. Additional groups would have to be included to allow for identification of variance due to practice effect, but this type of approach would seem to offer more control over idiosyncratic variations in individual performance such as the grade 8 males seemed to

manifest in this research.

For abstract pairs, only the grade 10 performance provided clear evidence of a facilitative effect of training. For the grade 12 students the contrast did not reach statistical significance, but the data themselves indicate that this was due to the inadequacy of the repetition instructions to inhibit elaboration rather than to a failure of trained subjects to produce elaborative events. For grade 6 the results of the analysis on the 12 original scores indicated that training did in fact facilitate recall but only for AH pairs and only by trial 3.

In summary, students as young as 11 years of age are clearly capable of carrying out the basic operations necessary for elaboration of noun pairs when prompted to do so. Level of meaningfulness only within the abstract pairs, but not within concrete pairs was found to limit the scope of generality of these operations, however. It would appear that some minimal level of "richness of associative possibilities" for a given child must be met if a semantic relationship is to be successfully created, at least given the ten second study interval used in this research. This significant difference associated with level of m within abstract pairs is doubly interesting when compared to the results of a previous study (Greer & Suzuki, 1976) which found grade 6 students unable to benefit from training with both AL (Mm = 3.54) and AH (Mm = 4.96) pairs. In the present research AH pairs with a mean m of 5.55 were elaborated but AL pairs with a mean m of 3.04 were not. Thus, if a minimal level of associative meaningfulness does exist for grade 6 students it would appear from these two sets of results to be somewhere in the interval between 4.96 and 5.55. Further research will be required to determine the reliability of the present findings, and

to allow for a more thorough examination of the boundaries of this sensitivity to level of associative meaningfulness.

The fifth and final question concerned the ability of subjects to use more than one strategy in which they had been trained, and to use these strategies preferentially in response to changing characteristics of the pairs to be learned. From the results of the self-report data it is apparent that students at all grade levels reported use of both imaginal and verbal strategies across the four pair types, as well as making spontaneous use of non-elaborative rote rehearsal. There is little doubt then that pre-adolescents and adolescents will employ more than one strategy if they are prompted to do so.

With regard to the second aspect of this question; interpreting Paivio's (1971) dual coding hypothesis, it was anticipated that verbal elaboration would be the preferred mode of elaboration for abstract pairs while both imaginal and verbal elaboration could be used with equivalent ease with the concrete pairs. Contrary to the expectation for concrete pairs, there was a very clear preference for imagery which increased with age to the point where verbal and non-elaborative forms of elaboration virtually disappeared by grade 12. It is the youngest age group who tend to use the two elaborative forms with equal frequency.

Selectivity is also seen among the oldest group for sentence elaboration of the AL pairs, in agreement with the predictions of the dual coding hypothesis. In fact among all ages verbal elaboration was the form used if an elaborative event was produced at all. It is interesting to note with these AL pairs that the compulsion to 'do something' by these trained subjects was sufficiently strong that when an elaborative event was not

forthcoming, they spontaneously defaulted to rote repetition. That is, once the individual realizes, either from internal prompting, by an executive control system or from external prompting, that something must be done now if later recall is to be ensured, then the elaborative process will default to a rote repetition operation if no other option is possible, given limitations placed by associative possibilities of the material for the child.

The strong preference for a single elaborative process (imagery) among older adolescents with the concrete pairs may be interpreted in several ways. First, it may simply be a procedure to avoid the additional processing demand potentially involved in switching strategies when not absolutely required. The preference for imaginal elaboration of concrete pairs then represents a "labor saving device". Alternatively, Paivio (1971) has suggested that concrete pairs are not only equally amenable to imaginal or verbal modes of processing, the imaginal mode has an additional advantage. Images, it is Paivio's contention, have the added advantage of serving as "conceptual pegs". When an interactive image is formed, the first member of the pair serves as a peg form which the second member can be 'hung', ready for retrieval. The high preference for the imaginal mode for concrete pairs and the equivalent use of imagery for AH pairs by grade 12 students would offer some support for this suggestion. It is further possible to conjecture that the recognition of this added superiority of the imaginal mode is an additional component of the development of the 'cognitive executive routine' responsible for such metamemorial functions. The pattern of results in Figure 6 for concrete pairs do indicate the major shift for trained subjects to preferential use of imagery to be at the grade 10 level, the time at which spontaneous elaboration is also found to

emerge in behavior. For the AH pairs, however, equal use of imagery and verbal strategies is not found until the grade 12 level, and selective use of verbal strategies for AL pairs does not occur until grade 12, even though grade 10 students are spontaneously elaborating these pairs (i.e., the executive routine is supposedly functional). Thus, the degree to which the data support the contention that selective strategy use is related to development of cognitive processes similar to those responsible for spontaneous elaboration is tenuous at best.

The third, and what the writer feels to be the most likely explanation for the preferential use of imagery for concrete pairs is the nature of the sorting task from which this information arose. Students were required to place each pair in one and only one category to indicate strategy usage (unfortunately precluding the opportunity to assess the degree to which 'dual coding' in both the imaginal and verbal modes may have been reported). Thus, the task itself may have served to encourage the reporting of consistent strategy usage, particularly if the subject was aware of the categories inherent in the list itself (i.e., concrete versus abstract pairs). In addition, while this self-report data is interesting and gives some general sense of the pattern of elaborative and nonelaborative strategy usage by the adolescents, a provisory note should be made. Because the information is given after-the-fact and self-report, it is possible that there is a considerable gap between what the student says he did and what he "believes" he did (assuming here that the introspective process does not allow for a report of what actually occured). For example, the subject may believe that he/she generated an image in the process of elaborating 'devil-idea', but is hesitant to say so because of anticipated difficulty in describing the image if

requested to do so. As a consequence, he/she reports having generated the phrase "a devil of an idea" to avoid the need for description of his image of "a little red devil with a light bulb flashing over his head", or some such thing. It is doubtful that having subjects overtly generate elaborators during study trials would avoid this possibility and produce a more accurate picture of strategy usage. In spite of the limitations of data of this sort, it is believed that this type of information serves to provide further credence to the more empirical and objective data.

Summarizing the information on elaborative training, preadolescents are clearly capable of carrying out the mental operations necessary to generate elaborative events of concrete and abstract pairs when given imaginal and verbal prompts. A minimal level of associative meaningfulness must be met by the nouns, however, if this process is to be successfully completed. When this minimal level is not met the most likely outcome is the use of rote repetition of information. All grades were prepared and able to use more than one strategy thoughout the mixed list. In terms of relative preference, reported use of imaginal forms of elaboration was clearly higher for concrete pairs, while verbal forms of elaboration were most often reported for abstract.

General Conclusion and Implications

At a more general level of consideration, the results related to the training component as well as those concerned with spontaneous elaboration suggest that a child, when given some direction in the use of his available cognitive skills, will go on to refine these and to develop more efficient ones on his own. In addition, not only does this type of short-term strategy instruction lead to achievement gains, as the results with sixth

grade children indicated. It also led to a very definite change in attitude. It was demonstrated in the data regarding perception of item difficulty by treatment group that younger subjects in particular less frequently reported items as difficult to learn when provided with guidance concerning potentially useful processing strategies.

The research also suggests that optimal timing of such intervention is both desirable and specifiable. For example, the results indicated that grade 6 students were not only very receptive to training such that it brought perfomance up to a ceiling level. It was also indicated that the extended experience with "easy" concrete nouns over three trials for the control students may have been sufficient to facilitate some consolidation of an executive control system responsible for spontaneous elaboration. The potential exists for uncovering other such critical periods which will allow for optimal use of instructions. With such timing, the child is not just provided with ready-made knowledge, but he is provided with activities of the type which will allow him to develop and consolidate his own processing skills relevant to that knowledge.

The results further suggest that optimal timing of particular content areas is desirable, an idea which is certainly not novel (Furth, 1970; Rohwer, 1971). If the child's existing cognitive structures are not receptive to the integration and interpretation of new information in a meaningful way, then short of rote learning over extended training sessions, little progress will be made. This point is illustrated by the pattern of performances of younger subjects with the AL pairs.

While the results related to formal operational abilities and elaborative propensity were somewhat disappointing, they do serve to emphasize a

point which has relevance both to future research in memory development, as well as to the investigation of instructional practices. If one is to successfully identify the conditions which produce optimal performance, or which activate the processes responsible for such performance, one must consider the microstructure of the task itself. It is unlikely that until the sub-processes involved in any new learning have been uncovered and specified that one can effectively predict the instructional conditions necessary and sufficient to facilitate the acquisition of these new cognitive abilities for any given developmental level. As Davidson (1970) has suggested, if we are to facilitate self-generated learning rather than inducing learning, then the task of education is the working out of the balance between structure and sequencing of materials and the capacity of the learner.

Finally, perhaps the most disturbing aspect of this research was the finding that almost one half of these children had never received advice concerning a skill as basic as storage and retrieval of information. Even more disturbing was the fact that the vast majority of teachers did not provide strategy information, and those who did recommened reliance on some unproductive form of rote repetition. It is eminently clear that the task of providing teachers with the knowledge and materials necessary for this essential type of instruction is not being fulfilled. Without a program of research of which the present study represents a small part, this need cannot be identified, nor the merits of various forms of intervention assessed, nor the parameters influential to success of such practices be determined. As Davidson aptly stated with regard to this type of research:

What is important, it seems to me is to take the information

produced by such research and find ways to translate that information into teachable cognitive strategies. That is, we must find out what can be done by way of teaching the child to generate his own linguistic structures, his own mnemonic and his own effective images. In fact, a wide variety of teachable cognitive strategies would help the child become a relatively independent learner, and the independent learner, I maintain, is the preferred "product" of education." (1970, p. 9).

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Appendix A

Selection Procedures for Paired Associates

Paired Associate List

Selection Procedures: The 32 nouns (16 concrete, 16 abstract) making up the 16 item paired associate list were selected from among a pool of 96 nouns for which m data for grades 6, 8, and 10 had been previously collected using Nobel's (1952) procedure (Greer & Suzuki, 1976). The initial criteria for the selection of these 96 nouns from among those provided by Paivio, Yuille, and Madigan (1968) were (1) associative meaningfulness rating of 4.00 or greater on the adult norms; (2) frequency count of 30 or greater on the Thorndike-Lorge (1944) scale; (3) one half of the nouns had scaled concreteness values of 6.50 or greater, and the second half of the nouns had values of 3.50 or less and were designated as abstract.

Within each grade and abstractness level mean m values were transformed into z scores for each noun. All those nouns with z scores of .50 or greater and -.50 or less within each grade were then identified with the intention of selecting from among these eight concrete and eight abstract nouns with z scores greater than or equal to .50 at all three grades (i.e. high m), and eight concrete and eight abstract nouns with z scores of less than or equal to -.50 in all three grades (i.e. low m). Unfortunately, an insufficient number of nouns met these criteria and some compromises were necessary to generate a sufficiently large pool of usable items. The final selection is provided in Tables A1 and A2. As can be seen, among CH nouns one noun in grade 6 (baby), one in grade 8 (house) and two in grade 10 (flower, ship) had z less than .50 but greater than zero. Among the CL nouns one noun in grade 6 (doll), one in grade 8 (fork), and three in grade 10 (iron, star, doll) had z greater than -.50 but less than zero.

Table A1

Associative Meaningfulness Data for 16 Concrete Nouns

	Grade 6		Grade 8		Grade 10	
	M	z	M	z	M	z
High m						
apple	7.00	.68	9.00	.63	9.83	1.48
bird	8.25	2.14	9.19	.81	10.33	1.93
fire	7.75	1.55	9.48	1.08	11.17	2.68
tree	7.88	1.70	9.24	.86	10.43	2.02
baby	6.76	.40	10.95	2.46	9.28	.99
flower	7.28	1.00	10.25	1.81	8.55	.34
house	7.79	1.60	8.56	.22	8.92	.67
ship	7.60	1.38	9.64	1.23	8.27	.09
M	7.54		9.54		9.60	
S.D.	.49		.75		1.01	
Low m						
barrel	4.21	-2.58	6.12	-2.08	7.00	-1.04
flag	5.50	-1.07	7.33	- .94	7.58	- .53
hammer	5.20	-1.42	7.59	- .70	7.27	- .80
pipe	5.67	- .88	6.24	-1.97	6.21	-1.75
fork	5.20	-1.42	8.12	- .20	7.09	- .96
iron	5.54	-1.03	6.04	-2.15	7.96	- .19
star	5.88	- .63	7.44	- .84	8.07	- .09
doll	6.17	- .29	7.11	-1.15	7.63	- .48
M	5.42		7.00		7.35	
S.D.	.59		.77		.60	

Table A2

Associative Meaningfulness Data for 16 Abstract Nouns

	Grade 6		Grade 8		Grade 10	
	M	z	M	z	M	z
High m						
death	6.33	2.33	7.12	.65	8.07	2.05
devil	6.24	2.24	8.15	1.33	7.10	1.22
fun	5.28	1.29	8.14	1.33	6.59	.79
law	5.84	1.84	8.55	1.60	7.48	1.54
science	5.68	1.68	8.30	1.43	8.07	2.04
time	5.72	1.72	8.45	1.53	7.83	1.84
love	4.60	.61	7.55	.94	6.23	.49
dream	4.71	.72	6.08	.03	6.36	.60
M	5.55		7.79		7.22	
S.D.	.64		.84		.76	
Low m						
fate	2.67	-1.30	3.29	-1.89	4.00	-1.39
fault	2.96	-1.02	4.20	-1.28	4.54	- .86
method	2.71	- .77	3.80	-1.54	3.43	-1.87
pride	3.21	- .77	4.26	-1.24	4.67	- .83
shame	3.04	- .94	5.32	- .54	4.27	-1.16
truth	2.88	-1.09	3.92	-1.46	4.32	-1.12
opinion	3.21	- .77	4.67	- .99	5.24	- .35
ability	3.67	- .31	4.07	-1.36	4.63	- .86
M	3.04		4.19		4.39	
S.D.	.32		.60		.53	

Among the AH nouns one noun in grade 8 (dream) and one in grade 10 (love) had z less than .50 but greater than zero, and among AL nouns one noun in grade 6 (ability) and one in grade 10 (opinion) had z greater than -.50 but less than zero.

Four seperate analyses of variance were performed on the m data for each of these groups of eight nouns (CL, CH, AL, AH) to examine differences across grades. In all four analyses these differences were highly significant (CH: $F(2,28) = 17.96$, $p < .001$; CL: $F(2,28) = 23.54$, $p < .001$; AH: $F(2,28) = 19.20$, $p < .001$; AL: $F(2,28) = 16.80$, $p < .001$). From the means presented in Tables A1 and A2 it can be seen that the pattern in each case was a large and significant difference between grades 6 and 8 and a very slight difference between the means for grade 8 and 10.

To allow for examination of the differences in m over item concreteness and to verify that high m items did differ significantly from low m items within each concreteness level, analyses of variance were performed for each grade level. The results for all three grades confirmed the fact that concrete items were significantly higher in mean m than abstract items (Grade 6: $F(1,28) = 137.87$, $p < .001$; Grade 8: $F(1,28) = 741.07$, $p < .001$; Grade 10: $F(1,28) = 102.01$, $p < .001$) and that high m items were significantly higher in mean m than low m items (Grade 6: $F(1,28) = 154.71$, $p < .001$; Grade 8: $F(1,28) = 134.71$, $p < .001$; Grade 10: $F(1,28) = 91.97$, $p < .001$). In addition, the lack of a significant interaction between concreteness and m levels in all three grades verified that, as planned, CH items were significantly different from CL items, and that AH items were significantly different from AL items

Because of the strong negative relationship between concreteness level and m at all three grades, it was not possible to select items that

would allow for examination of the influence of abstractness independent of level of meaningfulness in the list as a whole. In selecting items it was possible however, to achieve equivalence in m levels among the eight CL and the eight AH nouns. Analyses of variance performed on the m values of these 16 items at each grade level confirmed that these two subsets of nouns did not differsignificantly (Grade 6: $F(1,14) < 1.00$; Grade 8: $F(1,14) = 3.86$, $p > .05$; Grade 10: $F(1,14) < 1.00$). Thus, within the total noun pair list this subset of pairs permitted examination of the influence of level of abstractness on memory performance independent of level of meaningfulness.

Appendix B

Student Response Sheets for Formal Operations Instrument

Name _____ Male Female

Grade _____

Birth Date _____

If I put this flat piece of clay back on the scale will the two pans still be at different heights like they are now?

YES NO

Why? _____

_____

If I put this flat piece of clay back on the scale will the two pans be at the same height the way they were before one ball of clay was removed?

YES NO

Why? _____

_____

1. If I place the sausage in the glass, will the water go <u>above</u> the rubber band? YES NO

Why? _____

_____

2. If I place the sausage in the glass, will the water go <u>below</u> the rubber band? YES NO

Why? _____

_____

3. If I place the sausage in the glass, will the water go right back up to the same level as the rubber band?

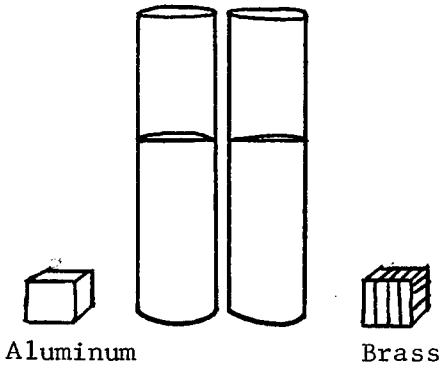
YES NO

Why? _____

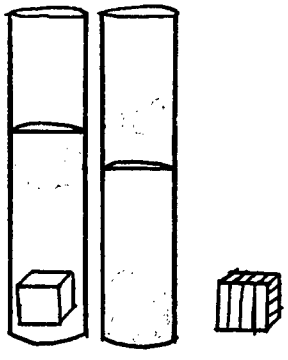
_____

Page 4

Here are two test tubes filled with equal amounts of water and two metal cubes. One is made of light aluminum and the other is heavy brass. These two cubes are exactly the same size but the brass one is heavier.



When the aluminum cube is put into one test tube the water comes up the test tube a little higher.



If the brass heavy cube is put into the other test tube, how high will the water come up? Will the water come up higher than the other test tube that contains the aluminum cube, lower than that one, or about the same amount? Draw a line on the test tube to show how much the water will come up. Explain why you think this is what will happen. _____

_____

_____

_____

_____

Do you think the piece of clay will float now that it has been flattened out? YES NO

Why? _____

_____

_____

If I put this piece that is left over into the water, will it still sink?

YES NO

Why? _____

_____

_____

If I put this little piece in now, will it float?

YES NO

Why? _____

_____

_____

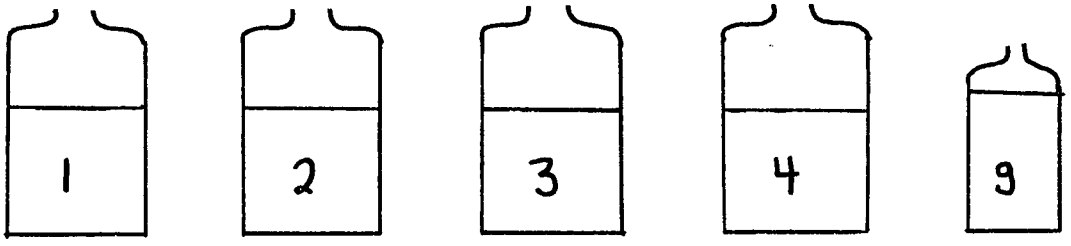
Do you think we could ever get a piece of clay small enough so that it would float? YES NO

Why? _____

_____

_____

This problem involves mixing chemicals together to make a yellow color. Here are four bottles of chemicals. Each one is different. There is also a small bottle called "g" which contains an activating solution. When "g" is added to certain combinations of the other four chemicals, they produce a yellow color.



Here are two glasses. Each contains some of the chemicals from the bottles shown above. When "g" is added to the glass marked A, it turns yellow. When "g" is added to the glass marked B, it stays the same and doesn't turn yellow.

Your problem is to figure out which combinations of chemicals along with "g" make the yellow color. Write down all the combinations of chemicals you would try out to find which ones make the yellow color. The amount of each chemical used is not important. You can assume that you have all the chemicals and all the test tubes you need and will not run out.

Make a list here of all the combinations you would try.

We tried out all the different combinations of chemicals with "g" and found that these were the results:

NO Color	YES, Yellow Color
1 + g	1 + 3 + g
2 + g	1 + 2 + 3 + g
3 + g	
4 + g	
1 + 2 + g	
1 + 4 + g	
2 + 3 + g	
2 + 4 + g	
3 + 4 + g	
1 + 2 + 4 + g	
1 + 3 + 4 + g	
2 + 3 + 4 + g	
1 + 2 + 3 + 4 + g	

1. What effect does Chemical Number 2 have on the reaction of making the yellow color?

2. What test or tests would you try out to see if these conclusions you made in Question 1 are correct? Why? (You may have done these tests earlier but if you were double-checking, which tests would you do again on the effect of Chemical Number 2?)

3. What effect does Chemical Number 4 have on the reaction of making the yellow color?

4. What test or tests would you conduct again to double-check your answer to Question 3? Why?

Here is a problem for you to think about:

> One summer a community offered a special hockey school to improve goal scoring. That winter a coach was looking over the records of goals scored by all the boys who played in the community league. The coach saw hockey school participants who scored a lot of goals, and boys who didn't attend the special hockey school, some of whom scored a lot of goals and some who hardly scored any at all.

Can the coach say anything definite about the effect of the summer hockey school on goals scored with this information?

YES NO

Why do you think that? _____

_____

_____

_____

_____

_____

_____

_____

Here is another problem to think about:

> I was looking at my friend's rose garden. He had been spraying his rose leaves with a chemical to kill a leaf disease. I saw sprayed leaves which were healthy and I saw unsprayed leaves, some of which were diseased and some healthy.

Can I say anything definite about the effect of the spray on the disease with this information? YES NO

Why do you think that? _____

_____

_____

_____

_____

_____

_____

_____

Appendix C

Pilot Testing of Formal Operations Instrument

Formal Operations Instrument

Pilot Testing

Subjects. A total of 65 students were administered the instrument during pilot testing. These included 23 (11 females, 12 males) grade 6 students, 15 (5 females, 10 males) grade 7 students who were members of two classes in a parochial elementary school in the Vancouver area, and 26 (21 females, 5 males) undergraduates enrolled in the Faculty of Education of the University of British Columbia. Mean ages of the three groups were 10.8, 12.0, and 21.4 years respectively.

Procedure. Administration of the items was undertaken in classroom groupings. Order of presentation of items was as follows: weight conservation, volume conservation, density conservation, 'Rose" problem of the propositional logic set, Chemicals task, 'Höckey' problem of the propositional logic set. The details of the method of presentation are as specified in the main body of this report. Care was taken to ensure that all subjects understood what was required of them, and were given adequate time to complete each problem to their own satisfaction. These times were approximately 70, 65, and 50 minutes for grades 6, 7, and college respectively.

In the week following the group testing, the pendulum problem developed by Inhelder and Piaget (1958) was individually administered to 20 of the grade 6 students, the intent being to determine the degree to which performance on this task related to that on the verbally presented Peel measures of propositional logic. Each child was presented with a pendulum in the form of a 20 inch string suspended from a clamp which was attached to a metal stand, along with a set of three weights (20, 50, 100 grams)

which could be fastened to a loop on the end of the string. The string could be shortened by wrapping it around the clamp. As well as size of weight and length of string, the other two variables which could be manipulated were height of release point and amount of force applied. Each child was shown the pendulum and was asked to carry out tests to try to find out what it was that made the pendulum swing fast or slow. All combinations of variables tried by the child and statements made were recorded by the experimenter. When a child indicated that he or she had completed experimentation and had not offered an explanation for all four variables, probes were given by the experimenter in the form "What about the effect of _____. Does it have anything to do with how fast or slow the pendulum swings?" "What tests would you do to prove that?"

In addition to the above testing, eight further grade 6 students who were not members of the above group,,but who had been given the full Formal Operations Instrument in their classroom group were also individually administered a version of the chemicals task prior to group administration. The procedure described by Inhelder and Piaget (1958) was followed, with the exception that Chemicals 2 and 4 gave the positive reaction, Chemical 3 was neutral, and Chemical 1 neutralized the yellow reaction. All sessions were recorded on electronic tape. If a child had not specifically dealt with the influence of chemicals 1 and 3 by the end of the session, the experimenter asked: "What about chemical _____, does it have any effect on the reaction? How would you test that to make sure?"

Results

(1) Piagetian Formal Operations Instrument: Scoring of all items was done according to the criteria specified in Chapter III of this work. Classification of explanations in response to the two Peel problems was

done independently by two judges. Interrater reliabilities for the Hockey problem was .98, for the Rose problem was .93, and for both problems combined was .96.

A summary of the item mean scores by grade is presented in Table C1. One way analyses of variance performed on these scores by grade were all highly significant ($F(2,61) = 7.58$, 16.02, 12.42, 11.19, 25.05, and 28.15 for weight, volume, density, chemicals task, Peel problems, and total score, respectively). The results of multiple comparisons among the grade means are presented in Table C1. In all cases but one (Chemicals task), grade 7 performance was significantly higher than that of the grade 6 students. The performance of college students was in turn significantly higher than the grade 7 students in all cases but one (density conservation). This unusually high performance of the grade 7 students on the density items (11 out of 15 students received perfect scores and no student scored less than five out of a possible 8) proved to be primarily due to an instructional effect in that this topic had been specifically dealt with in science class in the week immediately preceeding testing.

To provide some index of consistency of individual performance across items, intercorrelations among item scores and between item scores and total test scores were computed. From Table C2 it can beeseen that the majority of these correlations were significantly different from zero. Exceptions to this were those involving the density item, and that between weight conservation and the chemicals task. Again, the uniqueness of the results of density performance is probably due to Grade 7 students, as mentioned above.

To examine the nature of the distribution of scores at the three grade levels, the percentage of subjects at each grade level whose total

Table C1

FOI Item Mean Scores by Grade, and Grade Comparisons

	Grade 6		Grade 7		College		*t* Ratios (df = 61)	
	M	S.D.	*M*	S.D.	*M*	S.D.	6 vs 7	7 vs Col.
Weight (4)[a]	2.48	1.68	3.27	1.03	3.85	.78	4.29**	2.34*
Volume (8)	3.96	2.14	4.93	2.46	7.12	1.51	2.12*	5.44**
Density (8)	4.39	1.31	7.40	1.12	5.38	2.43	7.19**	5.45**
Chemicals Task (23)	10.43	4.71	11.00	6.52	17.15	5.29	.46	6.55**
Peel Problems (20)	4.70	3.11	7.33	3.98	13.38	5.45	2.61*	6.82**
Total (63)	26.30	9.20	33.93	9.96	47.08	10.99	3.40**	6.65**

a. Total score possible.

* $p < .05$

** $p < .01$

Table C2

Product Moment Correlations Among FOI Items for Pilot Sample (n = 66).

	1.	2.	3.	4.	5.	6.
1. Weight	-	.51**	.16	.20	.33**	.46**
2. Volume		-	.12	.42**	.54**	.68**
3. Density			-	.18	.17	.37**
4. Chemicals Task				-	.53**	.83**
5. Peel Problems					-	.85**
6. Total Score						-

** $p < .01$

score was less than 20, greater than 54, or within each 5-point interval between these two extremes was calculated. These data are presented in Figure C1. The positive skew of the distributions of the two younger groups and the negative skew in that of the college students is readily apparent even with these small samples. The mode for grade 6 was in the low 20's, for grade 7 in the low 30's, and for college students it was in excess of 45 out of a possible 63. The difference in range of scores for the three grade levels should also be noted. While 17 percent of grade 6 students scored less than 20, no grade 7 students scored less than 20 and no college students had scores less than 25. At the other end of the scale, no grade 6 student had a score in excess of 49 but this was not the case for the older two groups. In fact 23 percent of the college sample had scores in excess of 55 out of a possible 63 points.

(2) Pendulum Task: Using the protocol scoring system described by Inhelder and Piaget (1958), the 20 children were classified into the following five categories: I - Pre-operational; IIA - Early concrete operational; IIB - Consolidated concrete operational; IIIA - early formal operational; IIIB - Consolidated formal operational. None of the 20 children's performance was found to be typical of either of the two extreme categories (I or IIIB). However, three children were classified as early formal, 10 as late concrete, and 7 as early concrete. As the primary purpose for conducting this individual testing was to examine the relationship between verbally stated propositional logic problems (i.e. Peel problems) and the more traditional method using the pendulum, the performance of each of these groups of children on the Peel problems was of interest. Of the three children classified as IIIA, the average score on the Peel problems

Figure 1C. Distribution of students (percent of sample within grade level) by total score on the Formal Operations Instrument.

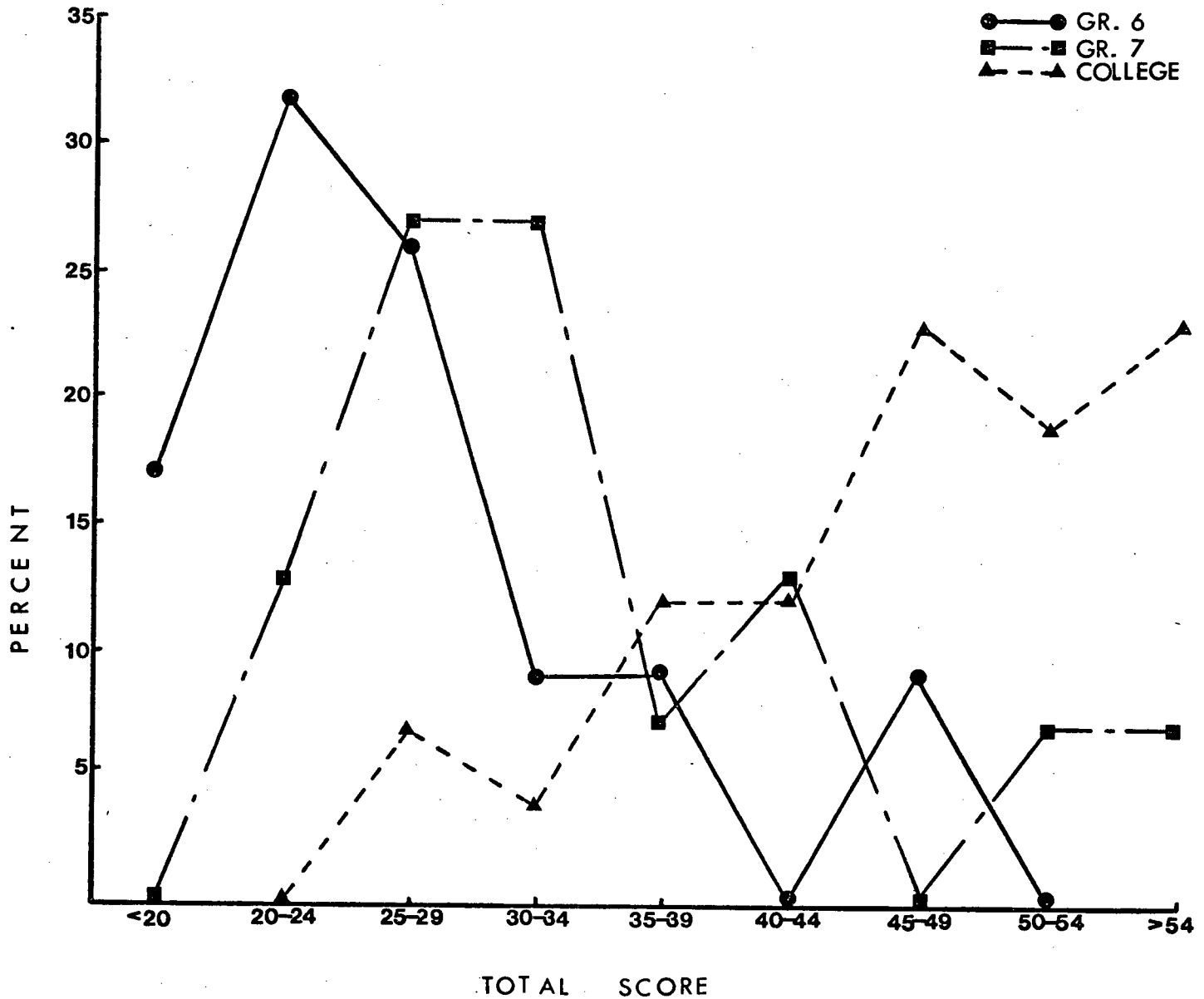

GR. 6
GR. 7
COLLEGE
PERCENT
35
30
25
20
15
10
5
<20
20-24
25-29
30-34
35-39
40-44
45-49
50-54
>54
TOTAL SCORE

FIGURE C1

was 10.67 out of 20. For the IIB and IIA groups respectively, these means were 4.80 and 4.00 on the Peel problems. In addition, none of the 17 children classified as concrete by the pendulum task scored in excess of 10 out of 20 on the Peel problems while two of the three children classified as formal operational did so.

To allow for further examination of the relationship between individual pendulum performance and scores on the group administered Formal Operations Instrument, percentages of children within each pendulum classification who passed or failed a test item were calculated. These data are summarized in Table C3. With the exception of the weight conservation task (a concrete operational task), the majority of children in the two concrete operational categories (IIA and IIB) scored less than 50 percent on the test items, while the reverse was the case for those classified as formal (IIIA).

(3) The Chemicals Task: The final aspect of the pilot testing was the individual administration of the Chemicals task to eight grade 6 children who were not part of the pilot sample of 23 grade 6 students referred to above, but who would receive the group administered version at a later date. Each unique combination of chemicals generated by the child received one point. The scoring of the responses to questions regarding determination of the influence of Chemicals 1 and 3 was identical to that described in Chapter 3 of this report. In order to examine the consistency of performance across presentation method, contingency tables were set up for each of the following: number of combinations generated (maximum = 15), score on hypothesis testing (Maximum = 8), and total Chemicals task score (maximum = 23). These data are presented in Table C4.

It is apparent that performance on the group administered version,

Table C3

Relationship between performance on group administered FOI (percent of sample scoring more or less than 50% on an item) and individually administered pendulum task.

		Performance on FOI									
		Score Less Than 50%					Score Greater Than 50%				
		Weight	Volume	Density	Chem.	Peel	Weight	Volume	Density	Chem.	Peel
Pendulum Task Performance (Piagetian Stage)	IIIB (0)[a]										
	IIIA (3)	00	00	33	00	33	100	100	66	100	66
	IIB (10)	50	80	60	60	100	50	20	40	40	00
	IIA (7)	43	71	57	71	100	57	29	43	29	00
	I (0)										

a. Number of children.

Table C4

Comparison of performance on individual versus group administration of the Chemicals Task to eight sixth grade children.

GROUP ADMINISTRATION

Combinations:

	0-3	4-7	8-11	12-15
0-3				
4-7		1		3
8-11			2	1
12-15				1

Hypothesis Testing:

Individual Administration

	0	2	4	6	8
0		1			
2		3	2		
4					
6					
8					2

Total Score:

	0-4	5-9	10-14	15-19	20-23
0-4					
5-9		1		1	
10-14			2	2	
15-19					2
20-23					

while not highly dissimilar from individual administration, tended to be greater in some students. For generation of combinations, four of the students achieved similar scores i.e. they fell on the principal diagonal. One students was only one interval higher on group administration, and three students moved up two intervals from individual to group testing. For the hypothesis testing segment of the task, scores across sessions tended to be more consistent. Five students fell within the principal diagonal of the table while three students scored one interval higher on group testing. In terms of total score, three students fell within the same score interval, four students moved up one interval, and one student moved up two scoring intervals.

Conclusions from Pilot Testing:

From this series of pilot tests a number of conclusions were drawn regarding the Formal Operations Instrument. First, the procedure proved to be a workable one under group testing situations for even the youngest subjects. Further no serious difficulties were encountered with equipment, response sheets, or timing.

Second, the instrument was an effective discriminator of performance of different grade levels, with older subjects consistently out-performing younger children (with the exception of the density conservation performance of seventh graders referred to above.). The distribution of scores at the three age levels examined were also consistent with what might logically be anticipated regarding the development of competence in formal operational thinking during adolescence. That is, the majority of 11 and 12 year olds failed to demonstrate competence while the reverse was true for the majority of 21 year olds.

Third, the significant intercorrelations among test items gives some

support, although recognizably limited, to the contention that the items are measuring a singular construct. Further, the pattern of significant correlations between each item and the total score gives some indication of internal consistency, and suggests that the various items of the scale are all measuring this underlying competence.

Fourth, the initial concern over the degree to which the demonstration of competence in propositional logic may be adversly affected by the verbal format of the Peel problems as compared to the pendulum problem appears to have been minimized by the pilot test results. Clearly the majority of those who are classified as concrete on the pendulum problem also do poorly on the Peel problems as well as on the other items making up the assessment instrument. Conversely, those who are classified as formal according to performance on the pendulum test are also those who are most successful on the Peel problems and the other test items. Obviously the results from 20 students do not allow for a formal test of this hypothesis of equivalence across methods, but they do serve to decrease concern over the appropriateness of the Peel problems for the purposes intended here.

Finally, the results of the individual versus group administration of the chemicals task did suggest some need for concern over equivalence of task demands. It was noted, however, that it was on the number of combinations generated that most improvement was found from individual to group testing. Only minor increases were found in the hypothesis testing aspect of the task. It should also be noted that it was possible to vary the nature of the hypothesis testing segment of the task by changing the numerical lables associated with the various chemicals. The 15 possible combinations that could be generated from four chemicals remained the

same from session to session, however. It seems reasonable to suggest then, that the increase in combinations generated from the individual to the group session was more likely due to a practice effect than to differences in testing mode. It is further proposed that the paper and pencil format of the group test was a more accurate assessment of competence in ability to generate combinations than was the individual testing situation with the additional distraction and confusion posed by the manipulationsof test tubes, jars, beakers, racks, droppers, and liquids.

On the basis of the foregoing, it was concluded that the paper and pencil group test was an acceptable device for assessment of Piagetian formal operational thinking as intended in this research.

Appendix D

Audio Protocol for Presentation of Paired Associates

Audio Protocol for Presentation of Paired Associates

This is your first study trial. You will see and hear 16 pairs of words. Pay close attention to each pair so that you will be able to remember which words go together when you have your first test. When the first study trial is finished then you will have the first test. Then you will have a second study trial and test, and finally a third study trial and test. Each time the pairs of words will be in a different order in the list, so don't try to remember which pairs come early and which pairs come later in the list. Just concentrate on trying to learn which words go together to make each pair. We will begin the first study trial now.

ability truth (10 second rate of presentation)
hammer doll
fire apple
love dream
star fork
fault opinion
tree baby
science death
pride fate
flower house
iron flag
law fun
pipe barrel
method shame
ship bird
devil time

We have completed the first study trial. Listen carefully. You will be given the first word of each pair. As soon as the word is given try to say the other word that went with it in the pair. Say your answer clearly so that it can be heard distinctly. If you are not sure of an answer don't be afraid to take a guess. Frequently your guesses are correct. You will have five seconds to give your answer. We will begin now.

science (5 second presentation rate)
ship
pipe
method
hammer
ability
fire
law

tree
fault
iron
devil
love
flower
star
pride

This is the end of the first test. Your second study trial will begin in a few moments. (Pause to change slide tray)

This is your second study trial. Remember, concentrate on trying to learn which words go together to make each pair. We will begin now.

(10 second presentation rate)

love dream
fault opinion
pipe barrel
flower house
method shame
fire apple
faw fun
star fork
science death
iron flag
pride fate
ship bird
devil time
ability truth
hammer doll
tree baby

This is the end of the second study trial. We will begin your second test. Remember to say your answers out loud and don't be afraid to take a guess. We will begin now.

(5 second presentation rate)

law
fire
iron
pride
tree
devil
hammer
ability
ship
method
love
star
flower
science
pipe
fault

This is the end of the second test. Your third study trial will begin in a few moments. (Pause to change slide tray)

This is your third study trial. We will begin now.

fire apple (10 second presentation rate)
pride fate
law fun
iron flag
tree baby
pipe barrel
devil time
ability truth
love dream
hammer doll
flower house
fault opinion
star fork
science death
ship bird
method shame

Thid is the end of the third study trial. We will begin your third and last test now. Remember to say your answers out loud in a clear voice and don't be afraid to take a guess.

love (5 second presentation rate)
tree
ability
pipe
flower
star
method
science
law
iron
fualt
ship
hammer
devil
fire
pride

This is the end of the third test.

Appendix E

Table E1

F-Ratios for Treatment Comparisons Within Grades With Two Covariates Removed.

	Univariate F's (d.f. = 1, 118)											
	Concrete Noun Pairs						Abstract Noun Pairs					
	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3
Grade 6												
MR - MT	29.47**	2.43	4.07*	< 1	< 1	2.19	2.29	< 1	< 1	< 1	< 1	< 1
MC - MT	15.24**	6.38**	5.09*	1.22	< 1	1.83	6.24**	< 1	7.26**	4.85*	2.17	< 1
Grade 8												
MR - MT	< 1	< 1	< 1	2.33	6.46*	< 1	1.31	< 1	2.68	< 1	2.89	< 1
MC - MT	3.60	2.97	< 1	< 1	< 1	< 1	< 1	5.11*	< 1	< 1	< 1	< 1
Grade 10												
MR - MT	10.58**	3.52	5.63*	2.42	< 1	1.12	4.83*	1.26	7.71**	< 1	< 1	< 1
MC - MT	1.27	< 1	< 1	1.72	2.92	< 1	1.65	2.95	< 1	< 1	1.66	< 1
Grade 12												
MR - MT	21.22**	14.89**	16.17**	< 1	1.77	< 1	2.61	< 1	< 1	1.00	4.24*	1.52
MC - MT	2.25	3.60	1.48	< 1	< 1	< 1	< 1	< 1	< 1	3.35	< 1	1.83

* $p \leq .05$

** $p \leq .01$

Note. R = Repetition, T = Trained, C = Control, T1 = Trial 1, T2 = Trial 2, T3 = Trial 3, T23 = M(T2 + T3), m = low m - high m.

Table E2a

F-Ratios for Grade Trends Within Treatment Conditions.

	Univariate F's (d.f. = 1, 120)											
	Concrete Noun Pairs						Abstract Noun Pairs					
	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3
Control												
Linear	14.88**	5.19*	1.39	1.08	1.04	1.44	15.44**	1.10	10.61**	<1	4.87*	<1
Quadratic	<1	<1	<1	1.14	3.52	<1	<1	4.45*	1.38	<1	<1	<1
Cubic	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.68	<1
Repetition												
Linear	5.52*	<1	2.69	<1	<1	1.27	6.66*	<1	<1	<1	<1	<1
Quadratic	11.63**	<1	3.64	1.14	2.80	4.76*	<1	1.98	2.70	<1	<1	<1
Cubic	5.19*	<1	<1	<1	<1	<1	1.56	<1	<1	<1	<1	<1
Trained												
Linear	1.67	1.80	<1	<1	1.16	<1	3.35	<1	<1	<1	3.24	1.88
Quadratic	4.02*	3.31	1.38	<1	<1	2.81	<1	<1	<1	1.23	<1	<1
Cubic	1.01	<1	<1	1.02	2.07	<1	<1	<1	<1	<1	<1	1.88

* $p \leq .05$

** $p \leq .01$

Table E2b

F-Ratios for Grade Trends Within Treatment Conditions With Two Covariates Removed.

	Univariate F's (d.f. = 1,118)											
	Concrete Noun Pairs						Abstract Noun Pairs					
	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3	Within	T1-T23	T2-T3	m	m x T1-T23	m x T2-T3
Control												
Linear	7.66**	2.39	1.20	1.26	<1	2.05	9.03**	2.15	8.41**	1.20	3.82*	<1
Quadratic	<1	<1	<1	1.20	3.59	<1	<1	3.68	1.22	1.11	<1	<1
Cubic	1.01	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.64	<1
Repetition												
Linear	1.42	<1	2.37	<1	<1	<1	2.45	1.38	<1	<1	<1	<1
Quadratic	8.85**	<1	3.39	<1	2.61	3.68	<1	1.37	2.78	<1	<1	<1
Cubic	5.00*	<1	<1	<1	<1	<1	1.42	<1	<1	<1	<1	<1
Trained												
Linear	<1	<1	<1	<1	<1	<1	<1	1.24	<1	<1	2.57	<1
Quadratic	5.21*	3.87*	1.38	<1	<1	2.35	<1	<1	<1	<1	<1	<1
Cubic	1.13	<1	<1	<1	2.09	<1	<1	<1	<1	<1	<1	1.84

* $p \leq .05$

** $p \leq .01$

Table E3

Mean Recall by Grade, Treatment, Sex, Trials, and Item Type.

	Trial 1				Trial 2				Trial 3			
	CL	CH	AL	AH	CL	CH	AL	AH	CL	CH	AL	AH
Grade 6												
Control:M	1.83	1.83	.50	1.33	3.17	2.83	1.67	2.17	3.50	3.50	2.67	3.17
F	1.83	1.17	1.17	1.17	3.50	2.50	.83	2.67	3.67	3.17	2.67	3.67
Repetition:M	1.00	.50	.17	1.50	1.83	1.50	1.00	2.67	2.83	2.00	2.00	3.17
F	1.33	1.17	.67	1.50	3.00	2.83	1.67	2.83	3.50	3.17	2.67	3.50
Trained:M	3.17	3.33	.50	3.00	3.83	4.00	2.00	3.83	4.00	4.00	2.83	4.00
F	3.17	3.17	1.17	2.50	4.00	3.83	1.83	3.50	4.00	3.67	2.33	4.00
Grade 8												
Control:M	1.00	1.17	.83	1.50	3.17	2.00	1.67	2.83	3.50	3.00	2.50	3.67
F	2.33	2.67	.67	2.33	3.67	3.83	2.50	3.83	3.83	3.67	3.67	3.83
Repetition:M	3.33	1.83	1.00	1.67	4.00	3.83	2.00	3.50	4.00	4.00	3.50	4.00
F	2.00	1.83	.83	1.67	3.50	2.67	1.50	2.83	3.83	3.33	2.33	3.83
Trained:M	1.67	2.00	.83	2.17	3.33	2.83	1.50	3.33	3.33	3.50	2.33	3.67
F	3.33	3.50	1.33	3.50	4.00	3.83	2.67	4.00	4.00	4.00	3.50	4.00
Grade 10												
Control:M	1.50	1.83	1.83	1.17	3.67	3.17	1.33	3.00	3.83	3.67	2.17	3.83
F	3.33	3.67	1.17	3.00	3.67	4.00	3.17	4.00	3.83	4.00	3.50	4.00
Repetition:M	2.33	1.33	.83	1.67	3.50	2.33	1.67	2.83	3.50	3.33	2.67	4.00
F	2.00	1.67	.67	1.67	3.33	3.00	1.83	2.83	4.00	3.67	3.17	3.67
Trained:M	3.00	2.67	1.33	3.00	4.00	3.83	1.83	3.67	4.00	3.83	2.83	4.00
F	3.67	2.83	1.33	3.00	4.00	3.50	3.17	3.67	4.00	4.00	3.33	4.00
Grade 12												
Control:M	3.17	3.00	1.17	3.17	4.00	3.67	2.83	3.83	4.00	4.00	3.67	3.83
F	3.00	2.50	1.83	2.83	3.50	3.67	2.67	3.50	4.00	3.83	3.17	3.83
Repetition:M	1.33	1.00	1.00	1.83	2.83	2.00	2.00	2.67	3.83	3.33	2.83	3.67
F	2.00	2.33	1.67	2.83	3.33	3.50	2.50	4.00	4.00	3.83	3.33	4.00
Trained:M	3.50	3.33	.83	3.67	4.00	4.00	1.83	3.83	4.00	4.00	3.17	4.00
F	4.00	4.00	1.50	3.50	4.00	4.00	2.67	4.00	4.00	4.00	3.83	4.00