AN INVESTIGATION OF THE OPERATIVE THEORY OF MEMORY

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Abstract

The study was concerned with the phenomenon of regressed memories within the context of the operative theory of memory (Piaget and Inhelder, 1973). Four pictures representing operative concepts of varying difficulty were presented to Grade Three children. Memory for these concepts was assessed through reproduction and recognition tasks. In addition, memory for the more arbitrary or figurative aspects of the stimuli was tested. Operative memory findings for three of the pictures coincided with results previously reported by Liben (1975). A different pattern of memory was found for the fourth stimulus representing the most operatively difficult concept. This latter finding appeared to fit predictions from the figurative memory hypothesis proposed by Furth, Ross, and Youniss (1974). Inconsistent relationships were evident between assessment and operative memory performance and the distinction between the figurative and operative aspects of the pictures was supported by the finding of different memory patterns for both types of information. Results were discussed in terms of possible variations in the role of memory (in the strict sense) across the four stimuli, problems with the assessments used to tap children's understanding of the Piagetian concepts, and the difficulty of predicting in advance the operative schemes to which children assimilate memory stimuli such as pictures. Finally, while Piaget and Inhelder's theory of memory can account for the findings of the present study, explanations derived from the theory suffer from a lack of clarity and a vagueness of terminology.

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An investigation of the operative theory of memory

Interest in memory research has had a long history in psychology. One of the oldest philosophical and experimental traditions in the study of memory is associationism. According to this view, memory consists of sensory information that is connected or associated in the mind. While the associationistic approach to memory remains popular (Anderson and Bower, 1973), alternative approaches have developed which reject many of the mechanistic notions implicit in associationism-namely, that the organism is a passive recipient of memory content, that recall is simply the reactivation of associative networks, and that the process of memory can be studied in an isolated compartmentalized fashion. These contemporary approaches to memory have taken a more organismic perspective. They emphasize the active role of the organism in determining what is remembered and how it is remembered, the largely reconstructive nature of recall, and the importance of studying memory in the context of the organism's perceptions, knowledge base, attitudes, etc.

Piaget and Inhelder's book, Memory and Intelligence (1973) represents an attempt to study memory from such a perspective. In this book, they present a series of studies that examine the relationship between memory and the developing cognitive structures of a child, an approach, heretofore, largely neglected. Piaget and Inhelder's interest in memory and intelligence stems from a long standing concern with the relationship between what they have termed the operative and figurative aspects of cognition. According to Piaget, the operative aspect of cognition refers to "the general knowledge which a child develops in the course of his normal experiences and which he habitually applied to various situations and tasks," (Furth, Ross and Youniss, 1974, p. 63). The operative aspect is dynamic, generali-

zable, and characterized by the ability to transform objects in the environment. These transformations can range from the overt actions of the sensorimotor period to the covert, internalized actions of operational thought. The figurative aspect of cognition refers to such activities as perception and imagery, whose roles are not to transform but to provide static representations of reality.

Both the figurative and operative components are involved in memory. Faced with a memorizable situation, we can distinguish between two aspects - the "raw" figurative contents of the event, that are perceived and can be represented as an image, and our understanding of the same event. Since Piaget had already developed the idea that the operative aspect was primary in directing such figurative functions as perception (Piaget, 1969) and mental imagery (Piaget and Inhelder, 1971), he hypothesized the same relationship when he turned to the study of memory, i.e. the figurative aspect of memory would be "embedded" in or directed by operative understanding.

To investigate this hypothesis, Piaget and Inhelder studied children's memories for a variety of configurations dealing with such notions as horizontality, causal processes, and numerical and spatial correspondence. While the details varied somewhat from study to study, the basic methodology used was as follows: Children were first presented with a configuration, and then brought back at varying time intervals ranging from a day to a year, and asked to recognize, to reconstruct, and/or to recall by means of a drawing, the originally seen configuration. The data from these investigations were analyzed for cross-age differences in the way the stimuli were remembered and for individual differences in subjects' performance from one test session to the next.

In one of the simplest experiments, Piaget examined the memories of three to nine year old children for a configuration of seriated sticks, (i.e. sticks of ascending height). Remembrance was tested by asking the children for a drawing of what they had seen, one week and eight months after the initial presentation of the configuration. The child's operational level of understanding for seriation was also assessed at the one week session. Analysis of the results of this study indicated that memory performance at one week paralleled the child's operative level of understanding. The children tended to reproduce the series in a manner that was similar to their performance on the seriation assessment. A comparison of the one week and eight month memory drawings revealed that 74% of the children had improved memories for the originally seen configuration. These improvements were gradual and appeared to reflect the substage development of the seriation concept.

These, and other similar results convinced Piaget and Inhelder that memory does reflect operative structures. What is remembered of an event is dependent upon what the child understands or to use Piaget's terminology, upon the relevant assimilating schemes that the child brings to bear when dealing with the event. When these operative schemes develop, this is reflected in the improvement or restructuring of the conserved memory image.

Several North American researchers have been involved in replications and extension of Piaget and Inhelder's work in memory. In one of the most extensive studies to date, Liben (1975) presented Kindergarten and Grade Four children with pictures expressing the concepts of seriation, horizontality, and verticality. Memory for the pictures was tested at one week and five months, by asking the children for drawings of what they remembered and through a series of recognition choice tasks. The children were also

tested for their operative understanding of the concepts expressed in the memory stimuli both before and after the memory portion of the experiment. This was important because the child's operative level was often only inferred and rarely directly tested in Piaget and Inhelder's work.

While the cross-age differences in the way the children remembered the various picture stimuli were consistent with Piaget and Inhelder's theory, the results from the within-subject analysis were not. Correlations between operative level and memory performance were weak and inconsistent and there was little evidence that the occurrance of memory improvements coincided with operative development.

Another problematic finding concerned the fact that while memory progression did occur, there were an equal number of memory regressions. The occurrance of a high number of regressed memories has also been reported by Furth et. al. (1974). In this study, children from Kindergarten to Grade Four were presented with four pictures, two of which represented concepts considered to be operatively difficult for children in this age range: a tilted bottle, half filled with liquid, and a falling and turning stick. Recall was tested at two hours, two weeks, six months, and one year intervals by requesting a memory drawing from the children. Many of the children were capable of accurate recall of the stick and glass pictures up to two weeks. After six months, however, they showed massive regressions in their ability to remember the conceptual or operative aspects of the stimuli, eg. the water level and the falling sequence of the stick.

Such findings would appear to be troublesome for Piaget and Inhelder's formulation of the relationship of memory to intelligence. If operativity follows a generally forward direction any memory change observed should be progressive rather than regressive.

Several explanations have been proposed to explain the occurrance of regressed memories. Liben (1974) has suggested that some observed regressions (and improvements) may be artifact of measurement errors and/or changes in subjects' attention, motivation, etc. between recall sessions. Another, more theoretical explanation proposed by both Furth et. al. (1974) and Liben (1974) is that early memory for some events is under the control of a figurative function which enables the child to remember information that can be in advance of his operative level of understanding. Through time this memory trace is schematized to reflect the child's current operative maturity. According to this explanation, regressed memories occur because children at initial recall sessions are reproducing a figurative image of the memory event. For some children these recall results present an inflated picture of his operative understanding. At later sessions, the figurative imitation fades and the child is more likely to be reconstructing the event relying on his current cognitive repertoire. Unless the relevant cognitive schemes are mature, memory performance will be poorer relative to the earlier session.

The only research to date that has directly tested the figurative memory explanation for regressed memories is a recent study by Liben (Note 1). In this study, Liben asked first and fourth graders, none of whom had an operative grasp or horizontality, to remember pictures based on this concept. In one condition, the children drew the horizontal elements in the memory stimuli themselves. They were then asked to remember their finished drawing, a stimulus that matched their operative level. In the second condition, the picture stimulus was provided by the experimenter and was in advance of the children's operative level. Recall was tested a week and seven months after initial presentation of the memory

stimulus.

Liben hypothesized that the children asked to remember the experimenter's drawing would produce more advanced drawings at one week than children in the drawing constructed condition. By seven months, however, their memories should have regressed. In contrast, the children in the drawing constructed condition should not show figuratively inflated memories and thus little regression in memory performance should be evident over the seven month retention interval.

The fourth grade data were consistent with the predicted pattern of results. Performance in the drawing provided group did decrease significantly between the two recall sessions but did not change significantly in the drawing-constructed group. The first grade data did not support Liben's hypothesis, however. Results from both conditions did not differ significantly between the one week and seven month session.

According to Liben, these findings suggest that older children are better than younger children at retaining a stimulus that is more advanced than their own conceptual level. This skill may be attributable to their greater experience with classroom tasks that require the copying and remembrance of new information. It is also possible that this ability is due to the older children's transitional understanding of the concept being tapped in the memory stimulus. In other words, children may not only remember what they can understand, as Piaget has argued, but also what they can potentially understand. The poorer performance of the first graders would reflect their rudimentary grasp of Euclidean spatial concepts.

It should be noted that both explanations contradict Piaget and Inhelder's formulation of the memory-operativity relation. According to Piaget and Inhelder the figurative aspects of memory are "embedded" in operativity so that memory is always a reflection of thought and not perception. As Liben suggests (1977) such a tight integration of memory and thought may be true only in relatively extreme cases when the subject's operative level is far below that tapped by the stimulus. In less extreme situations, the child may be able to extend his or her perception even for relatively long periods of time.

It could be argued from the standpoint of Piaget's theory that the remembrance of operatively advanced aspects of reality would be quite adaptive for the developing child. Even if such memories were sustained for brief time intervals they could play an important role as disequilibrating situations and prompts for cognitive growth.

To date the Liben study is the only research that has been specifically concerned with the idea of the figurative-operative continuum in memory and its potential for explaining the phenomenon of regressed memories. The present study intended to extend Liben's work in several ways.

The memory of Third grade children was tested using four pictures portraying three different concepts: seriation, verticality for stationary objects and hanging plumb lines adjacent to an incline, and the proportionality principle embodied in the workings of a balance. These concepts had been selected because they represent acquisitions for which children in this age range exhibit varying degrees of operative maturity. Seriation, should be a mature operative acquisition, verticality, a transitional one, and proportionality, a concept of which they would have only a rudimentary understanding. Using memory stimuli of graded difficulty was intended to

provide information on the question of whether the remembering of operationally advanced figurative knowledge is a general ability which varies with age or experience or whether it is a specific ability which varies as a function of the level of the child's understanding of the concepts embodied in the memory event. In order to confirm the predicted difficulty of each concept, subjects were assessed for their understanding of seriation, verticality, and the workings of a balance.

Both recognition and reproduction tasks were used to assess operative memory performance. Piaget and Inhelder maintain that there is a developmental priority to these two nemonic processes with recognition appearing earlier than reproduction. Both measures were included in order to determine if the pattern of retention for the four stimuli would vary as a function of the type of memory test.

The type of reproduction and recognition measures used was similar to those developed by Liben (1974, 1975), although modification of Liben's reproduction task was introduced. Liben provided much of the originally seen stimulus to the child and only asked for a reproduction of the omitted operative elements eg. nails, or flag. While some cues were provided for the child in the present study, they were kept to a minimum. This required the child to reproduce both the operative elements and their immediate context, eg. board with nails, hill with flag, etc.

One problem that has consistently occurred in previous research requiring memory reproductions is that children are unable to remember the stimuli. This is especially evident when the retention interval is quite long. To minimize this occurrance, children who reported lack of memories were prompted by the experimenter in order to cue recall and/or to help the child reconstruct the memory event.

Memory for the four stimuli was tested both at an initial recall session, (either immediate, one day or one week) and again at two months. The initial retention intervals included in the present study were shorter than those usually found in Piagetian-based memory research, since there is some indication that the operatively advanced figurative memory image may be a relative short-lived phenomenon. In the Liben (Note 1) study, for example, it is possible that the younger subjects in the drawing provided condition may have shown a figurative memory advantage relative to the drawing constructed group if the first recall session had occurred before a week. An additional group of subjects in the present study, were given only one recall session at two months. This condition was included to compare long-term memory performance with the results obtained for earlier retention intervals and to assess the possibility of test-retest effects from repeated memory trials.

In addition to examining the pattern of retention for the operative aspects of the stimuli, memory for the arbitrary or figurative information was also studied. Almost all of the past Piagetian-based memory research has concentrated on the fate of memory for the operative or conceptual aspects of memory stimuli. There have been two exceptions. Liben (1974) investigated figurative memory change over time in the remembrance of a tilted bottle including memory for details such as bottle orientation, shape, and colour. She was interested in the percentage of figurative improvements that occurred over time and found that they were less common than operative improvements. Similar findings were found in a study by Voyat (reported in Piaget and Inhelder, 1973). A group of four to seven year old children were shown an array of seriated sticks which varied in colour. While 33% of the subjects showed long-term improvements for the

seriated aspect of the stimuli, only 13% showed improvements for the colours. To gather additional information on the pattern of memory retention for both the arbitrary and operative aspects, the picture stimuli used in the study were designed to include both colours and pictorial details. In order to examine possible interactions in memory for both types of information, a division was made within each memory stimulus between those figurative details that were related to the representation of the operative concepts expressed in the drawings and those that were unrelated. These two divisions were labelled figurative-relevant, and figurative irrelevant, respectively. Memory for the figurative or arbitrary information was assessed through recognition tasks involving both the figurative-relevant and irrelevant aspects of each stimulus and by prompting colour recall of these same aspects.

An additional aspect of the present study involved an examination of the relation between operative assessment and memory performance. The correlational evidence reported thus far in the literature has been weak and inconsistent (Liben, 1974, 1975), counter to what Piaget and Inhelder's theory would predict. A replication of these findings was attempted.

METHOD

Subjects. Subjects were fifty-nine Grade Three children (25 males and 34 females) from two elementary schools in predominantly middle-class areas of Chilliwack, B.C. Three children were omitted from the sample because they were not available for all testing sessions. The mean age of the children at the beginning of the study was eight years, five months (range: eight years, one month to nine years, two months).

Design. The design of the memory portion of the study was a 4 (Groups) x $\overline{4}$ (Memory stimulus) x $\overline{2}$ (Time-of-Test) incomplete factorial design with repeated measures on the last two factors. Subjects were stratified by sex and randomly assigned so that comparable numbers of males and females were found across all four groups. Children in the first three conditions (Immediate, Day, and Week) were tested for recall twice, either immediately, one day, or one week after the initial presentation of the memory stimuli, and again at two months. The Group X Time-of-Test factors were not completely crossed, however, since subjects in the fourth group (Two months) were only tested at the two month memory session.

Procedure. Each child was seen individually on either four or five occasions by one experimenter, who was present for all sessions. The first and last sessions involved the pre- and post-administering of three assessment tasks. The two or three intervening sessions consisted of the presentation of the four memory stimuli and one or two memory tests depending upon the retention condition to which the child had been assigned. The assessment tasks preceded the memory portion of the study by two weeks and followed approximately four days to a week after the child's

final memory session.

All testing was done in a quiet area of the child's school. Subjects were seated at either a desk or a table at right angles to the experimenter, who was also seated. Each session began with the experimenter chatting with the child for about five minutes. The assessment periods lasted about twenty minutes and the recall sessions, approximately twenty-five to forty minutes.

Pre-Assessment Tasks. Each child was given three tasks assessing their understanding of seriation, verticality, and the workings of a balance. The order of the three assessments was randomly varied across each subject. The experimenter began by telling the child:

> I am now going to ask you to do some things for me. They will be like little games. None of them will be hard to do, and I think you will have a lot of fun.

Seriation assessment. The seriation task was similar to the procedure described by Elkind (1964) and is the identical assessment used by Liben (1975). Two sets of nine sticks, each 1.2 cm. wide were used as materials for the task. Set 1 sticks ranged from 3.6 to 14.4 cm.; Set 2, from 4.2 to 15 cm. In both sets, 1.2 cm. intervals separated sticks. As a preliminary test of size discrimination, the child was asked to pick the largest and smallest of five sticks randomly selected from Set 1. Children were then given all of the Set 1 sticks and asked, "Can you order these for me from smallest to largest?" If the child was successfuly, he/she was given five more sticks chosen randomly from Set 2 and asked, "Can you put these sticks in with those where you think they belong?" If the child did not succeed with the Set 1 task, five sticks were removed and he/she was asked to put only the remaining four sticks in order. The testing session

was ended if the child was unable to perform this task. If the child was successful with the smaller set, the five sticks that had been removed were reintroduced. The child was first given three of the sticks and then the final two, each time being asked to include them in his/her seriated array. If the complete set of sticks was seriated on this second attempt, the child, was given five of the Set 2 sticks and asked to insert them in his/her Set 1 series.

Verticality assessment. The verticality assessment consisted of two tasks adapted from McKay, Brazendale, and Wilson (1972). Both tests are identical to those used by Liben (1975) and are based on Piaget and Inhelder's (1956) work on the development of children's spatial concepts. The tasks are concerned with the child's representation of both stationary objects and hanging plumb lines relative to an incline.

For one of the tasks (Trees), the subject was shown a picture of a simple, upright pine tree on flat ground. The child was then given a booklet. On each of three pages of the booklet, a simple mountain was depicted (isosceles triangles of 30^{o}, 45^{o} and 60^{o}). The child was shown each mountain separately, and asked, "Can you draw two pine trees, like the one I showed you, one on each side of this mountain, so that they will look nice and straight?" In the second task (Trailor), the subject was first shown a picture of a trailor on flat ground with an electric lightbulb hanging from a wire attached to the inside roof. Subjects were then shown three mountains as in the Tree task. Depicted on the side of each of the mountains was a trailor. The experimenter presented each mountain separately to the child and said:

> These trailors are like the trailor I showed you. You can see that there isn't any lightbulb inside, though. Do you think you can draw a string and lightbulb inside the trailors, the way the string and lightbulb would look, if the trailors were going up and down the mountain, like this?*

While presentation of the three mountains always followed the order from gradual to steepest, the order of each task (Trees or Trailors) was varied randomly across subjects. For illustrations of the task see Figure 1, Appendix A.

Balance assessment. Materials for the balance assessment consisted of a wooden balance and a collection of steel weights. In each arm of the balance, nine cuphooks had been placed at varying positions from the fulcrum. The weights were small six-sided pieces of metal weighing one kilogram. At the top of each weight, there was a small hook, which enabled the weights to be hung on the balance and strung together to form collections of two or more kilograms.

The experimenter began by placing the balance in front of the child and demonstrating that the arms could be tipped if a finger or weight was applied to either side. The experimenter then brought out the weights and told the child that each weight weighed one kilogram and could be hooked together. The child was encouraged to try hooking the weights together to form strings of two and three kilograms. Following this, the nature of the task was explained to the child:

> We are going to play a kind of game, now, that will use the balance, and these weights. What I am going to do is to hold up different amounts of weights in each hand, and to position them along the arms of the balance like this. (A

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*In the instruction used by Liben (1975), the word "wire", was used instead of "string". It was felt by the present investigator, that the notion of wire may confuse the child into thinking that the lightbulb was somehow stiff and immoveable even on an incline. The word "string" was substituted to avoid this possible connotation.

> one kilogram weight was held in each hand of the experimenter, and aligned along several different positions on either arm of the balance.) What I would like you to do is to look carefully at the amount of weight I have in each of my hands, and to try to figure out what would happen if I were to hang these weights on these hooks. Would the balance stay straight out like it is now, or would it tip? Do you think you understand? Let's play one practice game to see if you do.

The experimenter then held one weight in either hand, in clear view of the child, and positioned them at the extreme ends of each balance arm. "What do you think will happen if I put this one kilogram weight here and the other weight here? Will the balance stay the same or will it tip?" If the child suggested the balance would tip, the experimenter asked the child to indicate which side he/she thought would be tipped down. After the child gave his/her answer, the experimenter hooked the weights on the balance and confirmed or disconfirmed the child's prediction.

The actual assessment consisted of seventeen situations (See Figure 2, Appendix A). All followed the format described above for the practice trial except that the child was given no feedback as to the correctness or incorrectness of his/her prediction. The weights were only aligned against the hooks but were never actually hung on the balance.

Presentation of the memory stimuli. The four picture stimuli used in the study were drawn in black ink on 8½" x 12" sheets of poster board. Outlines were filled in with felt marker colors. Three of the pictures representing seriation, and verticality for both stationary and hanging plumb lines were similar to the Nails, Flag, and Crane pictures used by Liben (1975). The Flag picture was adapted somewhat. Liben (a personal communication) suggested that only one flag be used instead of the two found in her original stimulus. The fourth drawing, See-saw was designed especially for the present study. It depicted three equal-size children, two on either

side of the halfway point on one side of the see-saw and the third child seated on the extreme opposite end. For illustrations of each stimulus picture, see Figures 1, 2, 3, and 4, Appendix B.

Nothing was said to the child concerning the relationship between the memory stimuli and the assessment tasks. After establishing rapport with the child, the experimenter told the subject:

> Today, I am going to show you some pictures, I want you to look at each picture carefully, and to try to remember them because, I am going to ask you about them later on

The four stimulus pictures were then shown to the child in random order. A short verbal context was provided with each picture.

> Nails. Have you ever used a hammer to hammer some nails? This picture shows the way a wooden board looks after someone has hammered some nails into it. Look at the picture carefully so you can remember what it looks like.

> Flag. Do you know that when explorers find new land, they usually put a flag into the ground to claim the land, to say it belongs to their country? This picture shows how it looked when an explorer tried to claim a hill but couldn't manage to get all the way to the top. Here is the picture. Look at it carefully so you can remember it.

> Crane. Have you ever seen a building being torn down. A machine that is often used to tear down buildings is a crane. This picture shows a crane going up a hill to knock down a house. Look at the picture carefully so you can remember it.

> See-saw. Have you ever played in a playground that had swings and a teeter-totter. This picture shows three children playing on the teeter-totter. They are all in the same grade and they are all the same size and weight. This is the way they are playing on the teeter-totter. Look at the picture carefully so you can remember it.

Memory sessions. The procedure for all memory sessions was identical. An interference tasks was given to the children in the immediate condition between presentation of the four picture stimuli and the actual memory test. This task required the child to connect a series of dots to form an outline

of a seal. The order of the memory trials for each stimulus picture followed the order of their initial presentation to each subject.

Memory for each picture was tested by first presenting the child with an 8" x 11" sheet of white paper containing the hammer (explorer, house or swings) found in the original stimulus. The experimenter began by saying to the child:

> Do you remember the picture I showed you with the hammer (explorer, house on hill, or swings)? Can you finish this picture so that it looks like the one I showed you? Just draw it as best as you can.

If the child indicated that he was unable to recall the picture, the experimenter would ask the child to try and remember the story the experimenter had given about the stimulus cue. In most cases this was sufficient to prompt recall. If not, the drawing sheet was put aside and brought out again at the end of the memory session. If the child still had difficulties, the experimenter encouraged the child to reconstruct the picture based on the presented cue, eg. "What do you think the picture could have been about? What are hammers usually used for?" Such prompting was effective in generating some type of recall in almost all of the remaining subjects. For those who still evidenced no memory, the experimenter told the child in a word, what the picture had contained, eg. nails, a flag, a crane, or a teeter-totter. At this point most of the remaining subjects remembered the drawing. Children who required some type of recall prompting were given a red pencil to draw the particular picture. This was done in order to distinguish the reproductions that did require prompting from those that did not. In addition a record was kept of the memory prompting required for each child.

Following the drawing recall of a stimulus picture the experimenter presented the child with two sets of recognition choices concerned with the figurative recall of two aspects of the memory stimulus, etc. the nails

and the board in the Nails picture. The child was also asked to recall the colours of these two aspects. Colour recall preceded each recognition choice. If the child was unsure of an answer to either the colour or recognition tasks, he/she was encouraged to give what they considered their best guess. An example of the protocol of the figurative memory aspect of the recall for the Nails stimulus follows:

> Do you remember what colour the nails were in the picture I showed you?
>
> One of these four pictures shows the type of nails that were in the picture. Can you look at them very carefully and pick out the one that shows the type of nails that you remember seeing?
>
> Do you remember the colour of the board the nails were hammered into?
>
> Here are four pictures. One of these pictures shows the board that was in the picture. Look at these pictures very carefully and pick out the one that you think shows the board that you remember seeing.

Figurative aspects of the remaining three memory stimuli included in the memory trials were: The hill and flag in the Flag stimulus; the crane and wrecking ball in the the Crane stimulus; and the children and teeter-totter in the See-saw picture.

An operative recognition task concluded the memory trial for each picture stimulus. Each set consisted of six pictures, one of which depicted the operatively correct memory stimulus originally seen by the subject. The other five choices contained either severe or minor operative errors. Recognition alternatives for the Nails, Flag, and Crane stimuli were supplied by Liben. The See saw choices were designed by the present investigator.

Post-assessment tasks. The procedure for the post-assessment tasks was identical to that outlined for the pre-assessment session.

Scoring.

Assessment results.

Seriation. Performance on the seriation assessment task was scored on a 8-poing scale developed by Liben (1975) and based on two criteria: the size of the largest set of sticks correctly seriated and the immediacy of results.

Verticality. Responses from the verticality assessment were scored according to the degree to which the trees and wires deviated from the true vertical. Those within 10^{o} of perpendicular were classified as high-level, those within 10^{o} of being perpendicular to the mountain side were classified as low-level, while those falling between these two criteria were classified as mid-level. Performance was summarized as the total number of high-level responses (range 0-12).

Balance. The balance assessment was scored (0-9) depending on the number of times the child correctly predicted the outcome of nine situations selected from the seventeen given to the child. A decision was made to only include the results from these nine trials since they represented situations the child was unable to use the strategy - the side with the heaviest weight, tips. In other words, they required an understanding of the proportionality principle to be solved correctly. The particular trials used in the assessment are indicated in Figure 2, Appendix A.

Operative memory.

Nail reproductions. Subjects reproduction scores for the Nails stimulus were scored according to a system developed by Liben (1975). A drawing was classified as high-level when it was either a perfect match to the original stimulus or showed a definite seriated pattern. A mid-level response

consisted of a drawing that was basically seriated but contained some minor discrepancies, eg. two sticks the same height. A drawing was rated as low-level if the depiction of the array was random or showed a series of sticks of even height. Drawings without nails or with nails scattered about were rated unscoreable and treated as missing data.

Flag and Crane reproductions. The Flag and Crane drawings were ranked high, mid, or low depending upon the degree to which the flag and chain deviated from the tree vertical. If these elements were within 10^{o} of correct verticality, the drawing was rated high-level, if within 10^{o} of the perpendicular, the drawing was rated low-level, and if the elements were somewhere in-between, the drawing was coded as mid-level. Drawings, in which the flag was ommitted or a tractor drawn instead of a crane were considered unscoreable. If a child drew the flag on top of a mountain, the drawing was also ranked as unscoreable.

See-saw reproductions. For the See-saw stimulus, a high-level responses consisted of an accurate reproduction of the 'twice the weight, half the distance from the fulcrum' arrangement of the figures on a level see-saw. A mid-level response was one in which the child either rearranged the figures, ommitted/added a figure, or tilted the balance in a manner that correctly represented one of two strategies: the side with the most weight tips, or equal weights on either side mean the see-saw is level. A low-level drawing was a reproduction for which none of the above was the case, eg. a level balance with one child on one end and two children at the other end. Finally, drawings were classified as unscoreable if the child gave only a partial drawing, eg. half of a see-saw or drew a see-saw from an aerial perspective making it impossible to determine if the child meant the balance to be tipped or not.

Recognition choices. Subjects' responses on the recognition tasks were scored as high-, mid-, or low-level depending upon the recognition choice selected.

For the purpose of the statistical analysis, the operative memory results were transformed in to a numerical score (High=3, Mid=2, Low=1). It might be argued that this conversion treats what should be considered ordinal data in an interval fashion. The advantage of the transformation is that it allows one to use summary statistics such as the analysis of variance. Whenever possible, however, the pattern of developmental responses (High, Mid, and Low) will be reported and discussed in conjunction with the results from the statistical analyses.

Figurative memory.

Figurative memory scores for each stimulus ranged from 0 to 4. Two points were given for each correct recognition choice and two points for each correct response to the colour question.

For each stimulus one recognition choice and colour recall question was classified as figurative-relevant and the other pair as figurative-irrelevant. A figurative-relevant score (0-8) and a figurative irrelevant score (0-8) were obtained for each subject by collapsing the results from the two pertinent recall measures across all four memory stimuli.

RESULTS

The memory data were analyzed to provide information on several points. One issue concerned differences in subject's operative memory across the four retention intervals, as well as changes across the four stimuli from one recall session to the next. These comparisons relate to the notion that early recall of operatively-advanced information is a figuratively-based reproduction while later recall is an operatively-based reconstruction.

Analysis of the pattern of memory across time and memory trials was also important in relation to a second major aim of the study, namely a comparison of the course of memory for the operative versus the figurative or arbitrary aspects of the memory stimuli. Additional analyses carried out to examine the different memorial consequences of figurative and operative information consisted of an investigation of the occurrance or non-occurrance ot test-retest effects and a comparison of the recall of figurative-relevant versus figurative-irrelevant information.

Information on these questions was obtained through analysis of variance tests. There is a complication in the use of this statistic with both the figurative and operative memory data, since the Group X Time-of-Test factors are not completely crossed. The children in the Two month condition were given only one memory trial while subjects in the Immediate, Day, and Week conditions received two. While an overall analysis of variance test was possible, it did not provide answers to some of the specific questions outlined above.

The recognition, reproduction, and figurative memory data were analyzed, then, in the following manner. One analysis of variance test was done on the initial memory (T1) results for each group, i.e. immediate vs. day vs.

week vs. two months. A second analysis specifically concerned with the question of test-retest effects, was carried out on the results obtained at two months (T2) from all four retention conditions. Finally, an additional analysis of variance test was done on the results obtained from the two memory trials (T1-T2) given to subjects in the Immediate, Day, and Week groups. While the results of this analysis overlapped considerably with the findings obtained from the two previous analysis, it was necessary in order to determine whether there were significant time-of-test effects or interactions.

The assessment data were analyzed to ascertain whether the predicted operative difficulty of the concepts used in the study were reflected in the children's assessment results and to determine through correlational analysis, if any relationships existed between assessment and memory performance.

Operative assessment results.

Since all subjects performed perfectly on the seriation task, analysis of the assessment results was confined to the verticality and balance assessments.

Means and standard deviations for males and females on both the pre- and posttests are found in Table 1. Improvements were evident for both assessments from the pre- to posttest, and males consistently outperformed females.

Results from the two subtasks of the verticality assessment: Trees and Trailors (see Table 1) indicate that the Tree portion of the assessment was easier than the Trailor section.

Table 1

Means and Standard Deviations for Males and Females on Pre- and Post-Verticality and Balance Assessments

			Verticality[a]		Balance[b]	
	n		Pretest	Posttest	Pretest	Posttest
Total Score	Male	24				
		M	6.75	8.042	2.042	3.667
		SD	3.24	3.22	1.78	2.407
	Female	32				
		M	3.875	5.5	1.063	2.406
		SD	3.03	3.58	1.34	2.107
Subtask						
Tree[c]	Male	24				
		M	3.77	4.75		
		SD	2.18	1.77		
	Female	32				
		M	2.2	2.56		
		SD	2.3	2.42		
Trailor[c]	Male	24				
		M	2.7	3.29		
		SD	2.07	1.92		
	Female	32				
		M	1.59	2.937		
		SD	2.04	1.933		

[a]Maximum Score = 12

[b]Maximum score = 9

[c]Maximum score = 6

Analysis of variance tests were carried out on both assessment tasks with Sex and Retention Group as between subject-factors and Time-of-Test as a within-subject factor. Results of these analyses (see Appendix C, Table 1 and 2) are consistent with the points described above. For the verticality assessment, both Sex $F_{(1,48)} = 12.804$, $p=.001$ and Time-of-Test, $F_{(1,48)}=11.661$, $p=.001$ were significant effects. No other effect or interaction reached significance. The same pattern of results was found with the balance assessment data. Again, Sex, $F_{(1,48)}=6.745$, $p=.012$ and Time-of-Test, $F_{(1,48)}=27.73$, $p=.001$ were the only significant main effects with no other effect or interaction reaching significance.

Operative recognition results.

An inspection of both the initial (T1) and two month (T2) operative recognition results (see Table 2) indicates that relative memory performance for the Nails, Flag, and Crane stimuli tended to parallel the operative difficulty of the concepts expressed in these pictures. There was a higher percentage of high-level responses for the seriation-based Nails picture than for the more operatively difficult, verticality-based Flag and Crane pictures. The fact that overall performance for Flag was better than for Crane is consistent with the assessment data. As was noted above, the concept of verticality in relation to objects adjacent to an incline (Flag) assessed through the Tree subtask, is a somewhat easier notion than verticality for hanging plumb lines (Crane) assessed in the Trailor subtask.

Moreover, the results presented in this table suggest that the pattern of memory performance across these three memory stimuli remains relatively constant across a two month interval.

Table 2

Developmental Level of Subjects' Recognition Choice by Retention Condition and Memory Stimuli

Group	n	Time of Test	Nail			Flag			Crane			See-saw		
			H	M	L	H	M	L	H	M	L	H	M	L
Immediate	12	T1	12	0	0	10	2	0	3	4	5	11	0	1
		T2	12	0	0	8	4	0	2	5	5	4	4	4
Day	14	T1	12	0	2	10	4	0	3	5	6	10	1	3
		T2	11	0	3	8	6	0	3	6	5	4	5	5
Week	15	T1	15	0	0	10	5	0	5	6	4	8	2	5
		T2	11	3	1	8	6	1	6	7	2	4	4	7
Two Month	15	T1,2	11	1	3	12	3	0	5	2	8	1	9	5

Note: Entries are number of subjects.

While stability appears to be the primary characteristic of the recognition scores for Nails, Flag, and Crane, the pattern of responses for See-saw was quite different. Although See-saw represents, supposedly, the most operatively advanced concept for children of the age range sampled in this study, this was not reflected in their memory performance. Recognition scores up to a week were characterized by a high occurrance of high-level responses, a higher number than was found for the Crane stimulus. By two months, subjects recognition memory performance had declined considerably, however, with most subjects giving mid- or low-level responses.

The developmental level of each subject's response was coded as a number (1-3). (For a summary of the means and standard deviations for the recognition data, see Table 3.) An analysis of variance test was run on the initial recognition data with Sex and Group as between-subject factors and Memory stimulus as a within-subject factor. The results of this analysis (see Appendix C, Table 3) are consistent with the observations noted above. There was a significant Memory stimulus effect, $F_{(3,144)}=21.22$, $p=.001$. Tukey (A) comparisons of the stimulus means revealed that memory performance for both Nails and Flag was significantly better than for Crane ($p < .01$). While the Group X Stimulus interaction was only marginally significant, $F_{(9,144)}=1.806$, $p=.072$, the fact that two month performance for See-saw declined considerably relative to the earlier retention intervals was reflected in a significant Group effect, $F_{(3,48)}=3.071$, $p=.036$. Post-hoc tests did not reveal any significant differences in Group means however. No other effect or interaction reached significance.

Table 4 presents within-subject data on the course of memory from the initial (Immediate, One Day or One Week) to the second memory session given at Two months. Entries on the diagonals indicate subjects whose memory per-

Table 3

Means and Standard Deviations for Operative Recognition Task by Memory Stimulus, Retention Condition, and Time-of-Test

Group	n	Time of Test		Memory Stimulus			
				Nail	Flag	Crane	See-saw
Immediate	12	T1	M	3.00	2.83	1.83	2.83
			SD	0.0	.389	.835	.577
		T2	M	3.00	2.667	1.75	2.00
			SD	0.0	.492	.754	.853
Day	14	T1	M	2.714	2.714	1.786	2.5
			SD	.726	.469	.802	.855
		T2	M	2.571	2.571	1.857	1.929
			SD	.852	.514	.77	.829
Week	15	T1	M	3.00	2.667	2.067	2.2
			SD	0.0	.48	.799	.941
		T2	M	2.73	2.6	2.267	1.8
			SD	.594	.507	.704	.862
Two Month	15	T1,2	M	2.53	2.8	1.8	1.733
			SD	.834	.414	.941	.594

formance remained stable from the first to the second trial. Entries above the diagonals indicate memory improvements, while those below are incidences of memory regressions.

Results for the Nails and Flag stimuli indicate that the commonest course of memory was stability or regression from a high to a mid-level response. Performance for Crane was more variable with some stability and an approximately equal occurrance of memory improvements and regressions. Finally, while some stability was evident for See-saw, there was an equal or greater occurrance of regressed memories.

An analysis of variance test was carried out on the recognition data for the Immediate, Day, and Week conditions using Time-of-Test as a within-subject factor. Memory stimulus was the second within-subject factor and Group was the between-subject factor. (Sex was collapsed across groups since preliminary analysis revealed that it was not a significant factor.) The results of this analysis (see Appendix C, Table 4) showed that Time-of-Test was a significant effect, $F_{(1,38)}=18.00$, $p=.001$ with initial recognition performance generally better than later results. The fact that memory for See-saw showed the greatest decline in performance across trials was reflected in a significant Time-of-Test X Memory Stimulus interaction, $F_{(3,114)}=4.403$, $p=.006$. A breakdown of this interaction by an analysis for simple main effects revealed that there was significantly better performance at T1 than at T2 for See-saw, $F_{(1,114)}=21.537$, $p. < .001$.

The only other effect to reach significance in this analysis was a Memory Stimulus effect, $F_{(1,38)}=18.006$, $p=.001$. The Group effect was not significant, $F_{(2,38)}=1.18$, $p=.318$. This finding is consistent with the results of the previous analysis which indicated that recognition memory remained relatively stable up to a week even for the See-saw stimulus.

Table 4

Relation between Subjects' T1 (Immediate, Day, or Week)

and T2 (Two Month) Recognition Responses

Developmental level of T1 responses	Developmental level of T2 responses											
	Nails			Flag			Crane			See-saw		
	L	M	H	L	M	H	L	M	H	L	M	H
Low (L)	2	0	0	0	0	0	8	5	2	3	5	1
Med (M)	0	0	0	1	6	4	2	9	4	1	2	0
High (H)	2	3	34	0	10	20	2	4	5	12	6	11

Note: Table records number of subjects.

Finally, a comparison of the T2 data (see Table 2) from the three conditions receiving an earlier memory trial with the Two month condition results did not show strong evidence for test-retest effect. When an analysis of variance test was done on the T2 data, (see Appendix C, Table 5) the Group effect did not reach significance, $F_{(3,48)}=.62$, p=.606. The remainder of the findings from this analysis, such as a significant Memory stimulus effect $F_{(3,144)}=19.214$, p=.001 are consistent with those already reported. Unlike the findings of previous analysis, however, there was a significant Sex effect in the T2 data, $F_{(1,48)}=6.468$, p=.014 with males outperforming females.

To summarize, the results from the operative recognition task revealed consistent differences in memory performance across the Nail, Flag, and Crane stimuli. The pattern of memory, i.e. the number of high-, mid-, and low-level responses, for these same stimuli, appeared to remain relatively stable over a two month retention interval and across memory trials. The See-saw stimulus, however, was characterized by a relatively high level of memory performance up to a week after which there was a decline in performance. In addition, See-saw was the only stimulus to show a significant drop in performance from the first to the second recall trials. No test-retest effect was evident and sex differences were only found for the T2 data.

Operative reproduction results.

Operative reproduction results for the four memory stimuli are found in Table 5 and 6. These results are based on all reproductions including those that required prompting. While the analysis of the reproduction data was similar to that for the recognition results, some changes were necessi-

Table 5

Developmental Level of Subjects' Reproductions by Retention Condition, Memory Stimulus and Time-of-Test

Group	n	Time of Test	Memory Stimulus															
			Nail				Flag				Crane				See-saw			
			H	M	L	U*	H	M	L	U*	H	U	L	U*	H	M	L	U*
Immediate	12	T1	10	2	0	0	6	6	0	0	1	9	0	2	6	0	6	0
		T2	12	0	0	0	4	7	0	1	1	9	0	2	1	6	5	0
Day	14	T1	12	2	0	0	8	4	0	2	2	8	1	3	7	1	6	0
		T2	11	1	2	0	7	5	0	2	0	11	1	2	0	6	8	0
Week	15	T1	7	0	5	3	9	4	0	2	1	12	0	2	1	6	5	3
		T2	10	1	4	0	6	8	0	1	3	10	1	1	0	5	8	2
Two Month	15	T1,2	5	2	7	1	5	3	0	7	0	10	0	5	0	2	9	4

Note: Table records number of subjects

* U=Uncodeable responses

Table 6

Means and Standard Deviations for Operative Reproductions by Retention Condition, Memory Stimulus, and Time-of-Test

Group	Time of Test	Memory Stimulus								
		n		Nail	n	Flag	n	Crane	n	See-Saw
Immediate	T1	12	M	2.833	12	2.5	10	2.1	12	2.0
			SD	.389		.522		.316		1.04
	T2	12	M	3.00	11	2.36	10	2.1	12	1.67
			SD	0.0		.5		.316		.65
Day	T1	14	M	2.7143	12	2.66	11	2.09	14	2.07
			SD	.726		.492		.539		.997
	T2	14	M	2.64	12	2.6	12	1.9	14	1.43
			SD	.75		.52		.288		.51
Week	T1	12	M	2.1667	13	2.7	13	2.07	12	1.67
			SD	1.03		.48		.2774		.65
	T2	15	M	2.4	14	2.42	14	2.14	13	1.38
			SD	.91		.51		.534		.51
Two Month	T1,2	14	M	1.857	8	2.62	10	2.0	11	1.18
			SD	.95		.517		.00		.404

tated due to the occurrance of missing data, i.e., subjects who could not remember a stimulus or gave an uncodeable drawing. Instead of overall analysis of variance tests on the T1 and T2 data, separate oneway analysis of variance tests were carried out for each memory stimuli. Group was the only main effect since preliminary analysis revealed no significant sex differences for any of the memory stimuli. An overall T1-T2 analysis of variance test was also carried out for the three test-retest groups, as was done with the recognition data. Source tables for all statistics are found in Appendix C, Table 6, 7, and 8.

Many of the findings from Table 5 and 6 were consistent with those reported above. There were significant differences in memory performance across stimuli with more high-level responses for the operatively easier Nails picture than for the more difficult Flag and Crane stimuli. Again See-saw was the exception with initial recall better than that found for Crane. In addition, the overall pattern of reproduction responses across retention intervals and recall trials for Flag and Crane was similar to that found with the recognition data.

Several differences between the reproduction and recognition results were noted, however. They involved for the most part differences in the stability of memory performance across time for Nails and See-saw. While recognition performance for Nails was characterized by considerable stability in the pattern of responses over a two month interval, the reproduction data showed a decline in memory at a week and more so at two months. Similarly, while the pattern of recognition responses for See-saw remained constant up to a week with decline evident at two months, this decline appeared as early as a week for reproductions.

The deterioration in performance for these two stimuli was reflected in the results from the two analysis of variance tests. As expected, the Group factor was significant in the T1 data for Nails, $F_{(3,48)}=4.214$, p= .01, and for See-saw, $F_{(3,45)}=2.8$, p=.05 (see Appendix C, Table 6). Post-hoc comparisons of both sets of group means indicated that the operative level of the reproductions was significantly higher at immediate, and one day recall than that reported at one week. The decline in performance at one week for these two stimuli was mirrored, as well, in the finding of a significant Group x Memory stimulus interaction in the T1-T2 analysis ($F_{(6,60)}=2.43$, p=.036 (see Appendix C: Table 7). Simple effects tests of this interaction indicated that there was both a significant Group effect for Nails, ($F_{(2,60)}=3.549$, p .05, and for See-saw, $F_{(2,60)}=2.486$, p < .10. A Duncan Multiple Range test revealed that Immediate condition performance was significantly better than performance at a week for Nails (p < .10). No significant differences in Group means was obtained for See-saw.

While there was some decline in recognition performance across memory trials, the Time-of-Test effect was not significant for the reproduction data, $F_{(1,20)}=3.71$, p= .068. The reason for this lack of significance is apparent from an examination of the within-subject responses across time (see Table 7). While memory regressions did occur for Nails, Flag and Crane, there was more evidence of stability and memory improvements for the reproduction findings than was found across trials in the recognition data. A finding consistent with the recognition data is the disproportionate number of memory regressions for See-saw, reflected in a significant Time-of-Test X Memory stimulus interaction, $F_{(3,60)}=10.867$, p=.001 (see Appendix C: Table 7). A simple main effects test revealed a Time-of-Test effect for See-saw, $F_{(1,60)}=27.692$, p < .001, with performance at

Table 7

Relation Between Subjects T1 (Immediate, Day, Week)

and T2 (Two Month) Reproductions

Development level of T1 reproductions	Developmental level of T2 reproductions															
	Nails				Flag				Crane				See-saw			
	U	L	M	H	U*	L	M	H	U*	L	M	H	U*	L	M	H
Unscoreable (U)	0	1	0	2	1	0	0	1	3	0	4	0	1	2	1	0
Low (L)	0	5	0	2	0	0	0	0	0	1	0	0	0	9	5	0
Mid (M)	0	0	0	2	0	0	10	4	2	1	25	2	1	3	3	2
High (H)	0	0	2	27	3	0	8	12	0	0	3	2	0	5	8	1

Note: Number of subjects is recorded in entries.

* U = uncodeable responses

T1 better than at T2.

A final point of comparison between the recognition on reproduction results concerns the occurrance of test-retest effects. While no such effect was found in the recognition data, there was a significant Group effect in the T2 data for Nails, $F_{(3,48)}=4.214$, $p=.001$ (see Appendix C: Table 8), with a Tukey (A) procedure indicating that the reproductions from the Two month condition were significantly poorer than that found for the Immediate and Day conditions which received an earlier memory trial ($p < .05$).

In conclusion the results from subjects' reproductions were more similar than dissimilar to the results obtained from their recognition memory performance. For both measures, there were across stimulus differences in memory performance and similar patterns of retention for Flag and Crane across two months. Considerable decline in long-term memory for See-saw was evident using both measures. Two divergences in the results from the two memory tests were the evidence of a test-retest effect and the finding of considerable less stability in reproductions of Nails.

Figurative memory results.

The results of the figurative memory data for each stimulus are reported in Table 8. As this table indicates figurative memory performance did not vary across memory stimuli. The one serious deviation from this pattern occurred with Crane. This reflects in all likelihood, the relative easiness of the colour and recognition choices for the wrecking ball which enabled many of the children to guess the correct answer without relying on memory. An examination of the results across retention conditions suggests that memory performance remains relatively constant up to a day,

Table 8

Means and Standard Deviations for the Figurative Memory Scores by Retention Condition, Memory Stimulus, and Time-of-Test

	N	Time of Test		Memory Stimulus: Nail	Flag	Crane	See-Saw
Immediate	12	T1	M	2.667	2.75	2.417	2.417
			SD	.888	1.215	.793	.9
		T2	M	1.833	1.917	2.417	2.167
			SD	.937	1.084	.793	.835
Day	14	T1	M	2.643	2.214	2.00	2.214
			SD	1.082	.893	.877	.893
		T2	M	1.929	2.071	2.143	1.714
			SD	.917	.997	.77	1.267
Week	15	T1	M	1.13	1.33	1.73	1.2
			SD	.834	.724	1.033	.862
		T2	M	1.73	1.4	2.0	1.667
			SD	1.792	.986	.756	.724
Two Month	15	T1,2	M	1.33	1.13	1.667	1.067
			SD	.976	.915	.724	1.033

with considerable decline in performance at a week and at two months.

The findings from an analysis of variance test on the T1 data revealed, as expected, no significant Memory stimulus effect, $F_{(3,156)}=.894$, $p=.446$ (see Appendix C, Table 9) but a significant Group effect, $F_{(3,52)}=17.772$, $p=.001$. Tukey (A) pairwise comparisons of the Group means showed that immediate recall was significantly better than that found at a week or two months, ($p < .05$).

When performance across trials was analyzed (see Appendix C, Table 10) there was no significant Time-of-Test effect, $F_{(1,38)}=2.246$, $p=.142$. There was, however, a significant Group X Time-of-Test interaction, $F_{(2,38)}=6.872$, $p=.003$. Analysis by simple main effects revealed a significant Group effect at T1, $F_{(2,38)}=15.302$, $p < .001$. A Neuman-Keuls test on the Group means indicated that the Immediate and Day condition results were significantly better than that found for the Week condition ($p < .05$).

Final analysis of the figurative data involved a test for the occurrance or non-occurrance of test-retest effects. The results of the T2 analysis (see Appendix C: Table 11) did reveal a significant Group effect, $F_{(3,52)}=5.249$, $p=.003$. A Dunnet T statistic (Winer, 1971, p. 202) on the Group means indicated that performance for the Immediate condition was significantly better than performance for the Two month condition which did not receive an earlier recall trial ($p < .05$).

In summary, the results for the figurative data can be contrasted with the findings from the operative memory data in the lack of variation in memory performance across the four picture stimuli, the decline in performance after a day for all stimuli, and finally, for clear cut evidence of test-retest effects across all stimuli.

Memory for the figurative-relevant versus figurative-irrelevant information.

An additional analysis of the figurative memory data involved a comparison of the pattern of memory for the figurative-relevant and figurative-irrelevant information, (see Table 9). Two analysis of variance tests were carried out on the T1 and T2 data with the Two month condition included in only the T2 analysis. For both analyses, Group was a between-subject factor and the figurative score (relevant or irrelevant) was a within-subject factor. The results of these analyses (see Appendix C: Tables 12 and 13) revealed a significant figurative score effect at both T1, $F_{(1.38)}=4.971$, $p=.032$ and T2, $F_{(1,52)}=6.722$, $p=.012$ with the figurative relevant information remembered better than the figurative-irrelevant. The Group effect was also significant in both analyses: T1, $F_{(2,38)}=15.629$, $p=.001$ and T2, $F_{(3,52)}=5.249$, $p=.003$. No significant interactions were found in either analyses. Tukey (A) comparisons of the T1 Group means revealed that, both the Immediate and Day condition results were significantly better than the Week and Two Month results ($p.<.05$). For the T2 data, the Immediate condition results were significantly better than performance for the Two Month group ($p.<.05$).

Relationship between assessment and memory performance.

The relationship between subjects' assessment performance and both operative recognition and reproduction memory was assessed through Pearson product-moment correlations. Since all subjects performed perfectly on the seriation task, correlation between assessment and memory performance for Nails were precluded.

Table 10 presents the results of the correlations relating overall verticality performance, and the two subtasks: Trees and Trailors with memory for Flag and Crane. Subjects assessment scores were correlated with

Table 9

Means and Standard Deviations for the Figurative-Relevant and Figurative-Irrelvant Scores by Retention Group and Time-of-Test

Group	n	Time-of-Test		Figurative Relevant[a]	Figurative Irrelevant[a]
Immediate	112	T1	M	5.417	4.833
			SD	1.782	1.642
		T2	M	4.75	3.583
			SD	2.006	1.505
Day	14	T1	M	5.214	3.857
			SD	1.929	1.099
		T2	M	4.286	3.571
			SD	1.684	1.284
Week	15	T1	M	2.733	2.667
			SD	1.534	.976
		T2	M	3.467	3.33
			SD	1.506	1.543
Two month	15	T1,2	M	3.00	2.2
			SD	1.464	1.082

[a]Maximum score = 8

both the T1 and T2 memory performance for the Immediate, Day, and Week group combined. In addition, the post-assessment scores were correlated with the combined T2 memory results from all four retention conditions.

The pattern of correlations from the pre-assessment results are consistent across T1 and T2 memory performance. Most of the significant correlations occurred for Crane. Both T1 recognition, $r_{(41)}=.2778$, $p=.04$ and reproductions $r_{(38)}=.2902$, $p=.048$ for Crane were significantly related to the total verticality assessment scores.

T2 recognition, $r_{(41)}=.4322$, $p=.002$ and reproduction, $r_{(36)}=.313$, $p=.036$ results for Crane were significant, as well. There was only one significant correlation for Flag with performance for the Tree subtask significantly related to Flag reproductions at T1, $r_{(39)}=.3319$, $p=.022$ and at T2, $r_{(37)}=.3482$, $p=.017$.

The correlations from the two subtasks of the verticality assessment suggest much of the predictive value of the Verticality scores is attributable to the Tree subtasks and not to Trailors.

The pattern of correlations relating post-assessment and T2 memory performance differed from those just described in that there were more significant correlations for Flag than for Crane. The verticality scores were significantly related to both the Flag recognition, $r_{(56)}=.3502$, $p=.004$ and reproduction, $r_{(45)}=.2748$, $p=.034$ results, with no significant correlations for Crane. Again, the results suggest that the Tree subtasks predicts as well, if not better than the total verticality score.

Results of the correlations relating the balance assessment and memory performance for See-saw were non-significant except for one instance. The pre-assessment results were significantly related to T2 memory performance for the Immediate, Day, and Week groups combined, $r_{(41)}=.3192$, $p=.021$.

Table 10

Pearson Product Moment Correlations Relating Total Verticality Assessment (VT) and Subtask: (Trees) and (Trailor) with Memory Performance for Flag and Crane

			T1 Memory			
			Flag		Crane	
	Pre-assessment		Recognition	Reproduction	Recognition	Reproduction
Immediate	VT	r	.2471	.1416	.2778*	.2902*
+		p	(.06)	(.202)	(.039)	(.048)
		n	41	37	41	34
Day	Tree	r	.2531	.3319*	.313*	.1104
+		p	(.055)	(.022)	(.023)	(.267)
		n	41	37	41	34
Week	Trailor	r	.0931	-.1472	.0724	.2705
		p	(.281)	(.192)	(.326)	(.061)
		n	41	37	41	34
			T2 Memory			
Immediate	VT	r	.0043	.1937	.4322**	.313*
+		p	(.489)	(.125)	(.002)	(.032)
		n	41	37	41	36
Day	Tree	r	.1304	.3482*	.448**	.2399
+		p	(.208)	(.017)	(.002)	(.079)
		n	41	37	41	36
Week	Trailor	r	-.1412	-.0938	.1583	.2266
		p	(.189)	(.29)	(.161)	(.092)
		n	41	37	41	36
			T2 Memory			
	Post-assessment					
Immediate	VT	r	.3502**	.2748*	.2133	.2311
+		p	(.004)	(.034)	(.057)	(.061)
		n	56	45	56	46
Day	Tree	r	.3566**	.2726	.2168*	.2326
+		p	(.004)	(.035)	(.05)	(.06)
		n	56	45	56	46
Week	Trailor	r	.222 *	.1696	.1349	.2697*
+		p	(.05)	(.133)	(.161)	(.035)
Two Month		n	56	45	56	46

* $p \leq .05$
** $p \leq .01$

In conclusion, the results of the correlation analysis do not provide strong empirical support for the hypothesized relationship between assessment and memory performance. While there was evidence of significant relationships for verticality, the correlations found were neither strong nor consistent.

Discussion

While the assessment data were not a primary concern of the present study, the results provided an independent measure of the operative difficulty of the concepts represented in the memory stimuli, and did permit a reexamination of some of the assessment/memory relationships previously reported by Liben (1974, 1975).

Performance on the assessment tasks conformed with expectations. Seriation was the easiest task with all subjects performing perfectly. The verticality assessment was of medium difficulty, while subjects performed most poorly on the balance task. As Liben had found, males outperformed females on the verticality assessment and a similar sex difference was found in the balance assessment.

The most important aspect of the assessment results concerned their relationship with memory for the related stimuli. While some significant correlations were found between verticality and memory for Flag and Crane, the results were weak and inconsistent across both memory stimuli and type of memory test. These findings parallel those reported by Liben (1975).

A novel finding concerns the relationship between memory performance and the results from the two subtasks of the verticality assessment: Trees and Trailors. The correlations indicated that the Tree subtask was as good a predictor of memory performance for both Flag and Crane as the total verticality score. The finding of so few significant relationships between Trailor and Crane is somewhat surprising since the task subjects were given in Trailor and the example of verticality expressed in Crane appear to be conceptually identical.

There are several possible explanations for these non-existent and weak relationships. The assessments may be inadequate. From a Piagetian perspective, a short paper and pencil test, such as the verticality assessment would not be considered an adequate probe of a child's understanding of a concept. The lack of findings may reflect the fact that the memory for the operative aspects of stimuli such as pictures, is based on schemes that are not predictable in advance or consistent across all children. It is possible that the use of memory stimuli that involve the child in more active and specific interactions would result in more convincing empirical evidence.

Another explanation is that the memory stimuli and assessment tasks are not operatively related. This may be a valid conclusion in the case of the See-saw. The incidence of significant correlations between See-Saw and the balance assessment was neglible. While more evidence of a relationship might have occurred if the subject sample had included older children, i.e. children closer to formal operations, the assessment was in all likelihood tapping something more rudimentary than the proportionality principle as Inhelder and Piaget (1958) have developed the idea. Consistent with this, is the fact that performance for both the verticality and balance assessments improved significantly from the pre- to the post-assessment session. While improvements in verticality would not be surprising given the transitional nature of subjects' understanding of the concept, it is somewhat counter to theoretical expectations for there to be a significant improvement in performance for the balance assessment. Proportionality is supposedly an advanced operative acquisition, thus one would expect little development of the concept to be evident for most subjects until much later.

In the case of the other three memory stimuli, the operative component of each does appear to be directly related to the corresponding assessment. A final explanation is that there may be considerable differences in what is being coded as operative memory across the memory stimuli. This latter interpretation is developed below after a consideration of the memory results.

The two memory tasks, reproduction and recognition, yielded generally parallel patterns of operative memory. Consistent with Piagetian theory and with results reported by Liben (1975), there were more high-level responses for the operatively easier Nails stimulus than for the two operatively transitional Flag and Crane stimuli. This variation in memory performance across stimuli was evident as early as the immediate test and remained relatively constant with one exception to be discussed later, across the day, week and two month memory trials. No significant test-retest effects were evident.

The pattern of memory for See-saw was different. Performance for See-saw was marked by an initially high-level of accurate memory which declined after a day for reproductions and after a week for recognition results. Moreover, subjects' performance on both measures declined significantly from the initial (immediate, day, or week) memory test to the second memory session at two months. No test-retest effect was the only finding with See-saw that overlapped with that obtained for the Nails, Flag, and Crane stimuli.

The findings for See-saw appear to be a perfect demonstration of the figurative memory hypothesis. While the children were not operatively equipped to assimilate the proportionality concept expressed in the stimulus, they were able to rely on a figurative memory trace to recognize and to reproduce the stimulus in the immediate memory trial. The capacity to

reproduce the picture declined quickly, while recognition declined more slowly. By two months, this figurative memory trace had faded and as the results indicated, the children were unable to recall the operative elements of the stimulus accurately.

The notion that memory regression occurs for events the child has a transitional understanding of is not supported by these findings. The See-saw related to an advanced concept, yet regression did occur. The two transitional stimuli, Flag, and Crane, were not associated with regression. An alternate explanation for these findings is as follows. The four stimuli may vary in terms of the contribution of memory (in the strict sense) to the representation of the operative elements. It is possible, that most children do not even notice the verticality of the flag and chain in the Flag and Crane stimuli since the actual orientation of these elements is not central in either picture. It is also likely that there is no memory involved in the direction the children orient the flag and chain in their reproductions. Instead, subjects may supply or infer such details on the basis of their operative schemes (memory in the broad sense), i.e., how they understand the concept of verticality. The finding of consistent operative memory performance across time for the Flag and Crane stimuli may reflect this lack of authentic memory.

It could be argued with the Nails and See-saw stimuli, that the operative aspects (seriated nails, proportionality principle expressed in the arrangement of figures on a See-saw) are more central. Unless the child can reconstruct a memory image (in whatever form) of what these stimuli are about, he will not be able to give operatively correct responses. Thus the pattern of results may reveal more about the properties of the stimuli and the scoring procedure than about the role of operativity in

memory.

Piaget and Inhelder (Chapter 13, 1973) have noted memory regressions of the sort obtained here. They review an experiment in which children's memories of an incomprehensible causal process over a six month period were examined. The results of the study indicated that children who did not have an operational understanding of causality were able to accurately recall the depicted causal events up to a week. Piaget and Inhelder argue that despite their immature operative schemes, they were able to derive a pseudo-lawful explanation of the event. These explanations provided a framework that enabled the child to organize his memory and to accurately reconstruct the event for a short time. The organization responsible for the conservation of this memory was as unstable as the child's developing understanding of causality. Thus the occurrance of a dramatic decline in memory evidenced at six months.

It is likely that Piaget and Inhelder would invoke a variation on this explanation to account for the occurrance of regressed memories as have been found for the See-saw stimulus and which North American researchers such as Furth, et. al. (1974) and Liben (1975a) have reported. The disturbing quality of this explanation is that the operativity hypothesis takes on a fluidity bordering on the elusive. That is, one can wonder what research finding could not be interpreted as consistent with the concept of operative schemes. In any event, the current results suggest that children do remember information that they do not understand. This aspect of memory, even if shortlived, may have an important epistemological role for the developing child.

The value of the figurative or arbitrary-operative distinction was confirmed by the different pattern of results obtained for the two types of information. First, figurative memory did not vary across stimuli, while

memory for the operative aspects did. Secondly, memory for the figurative aspects "decayed" rapidly with time. Finally, there were test-retest effects such that an initial test improved the two month memory for the figurative aspects. These results indicate that operative and figurative memories are distinct. The figurative memory pattern could be accounted for within the Piagetian framework. The decline in memory for these arbitrary or non-conceptual elements could be interpreted as consistent with the assumption "that memory collaborates with the schemata of intelligence". While the figurative - relevant, figurative-irrelevant findings may be an artifact of children's attention to different details, the occurrance of better memories for figurative information related to the representation of the operative concepts would also be consistent with an Piagetian perspective. Presumably, the ameliorative effect of an earlier recall trial could also be interpreted as having made the figurative information more functional and thus increased the likelihood that it would be assimilated to differentiated schemata. While such theorizing is possible, it again appears somewhat elusive and unsatisfying. The contrasting pattern of findings for the factual versus conceptual information would appear to demand a clearer explanation. One important measure of the future value of the operative approach to memory will depend upon the extent to which it can be developed to provide a coherent account of findings such as the above.

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Reference Note

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APPENDIX A

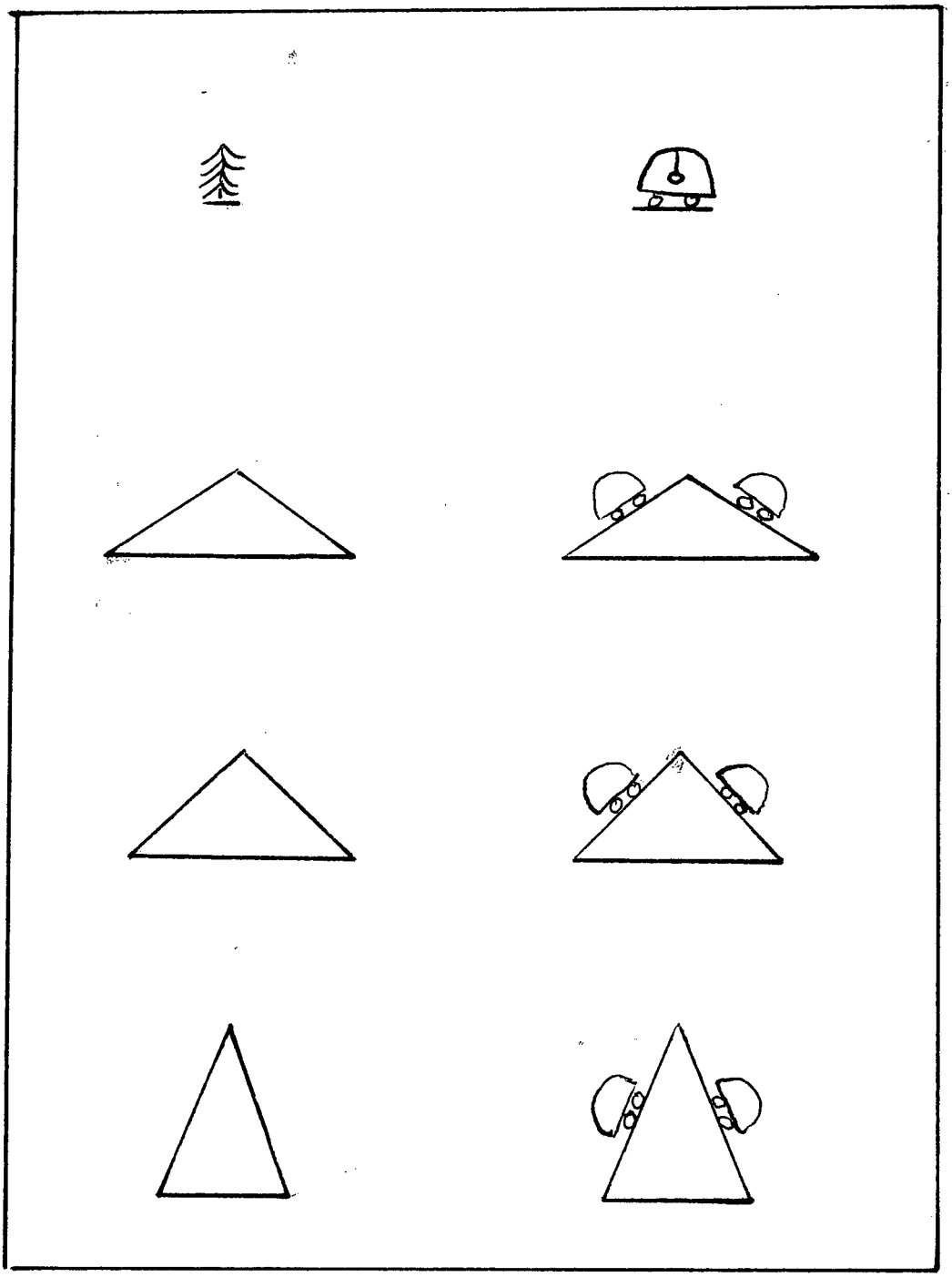

Figure 1. Verticality assessment tasks: Trees and Trailors.

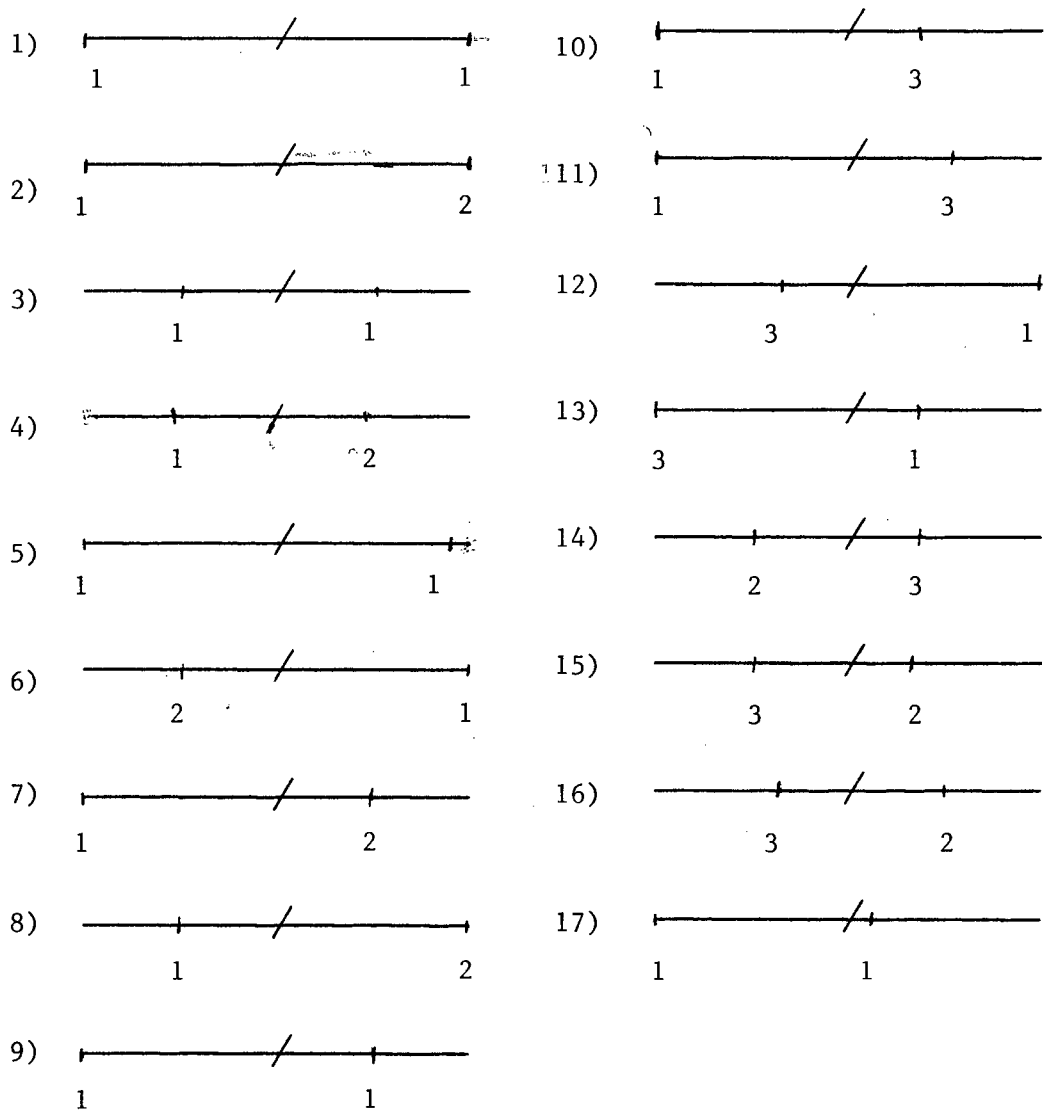

Figure 2. Schematic of situations used in Balance assessment.[a]

Note: Numbers indicate weights in kilogram.

[a]Situations scored for assessment are 3, 5, 6, 7, 10, 12, 14, 16, 17.

APPENDIX B

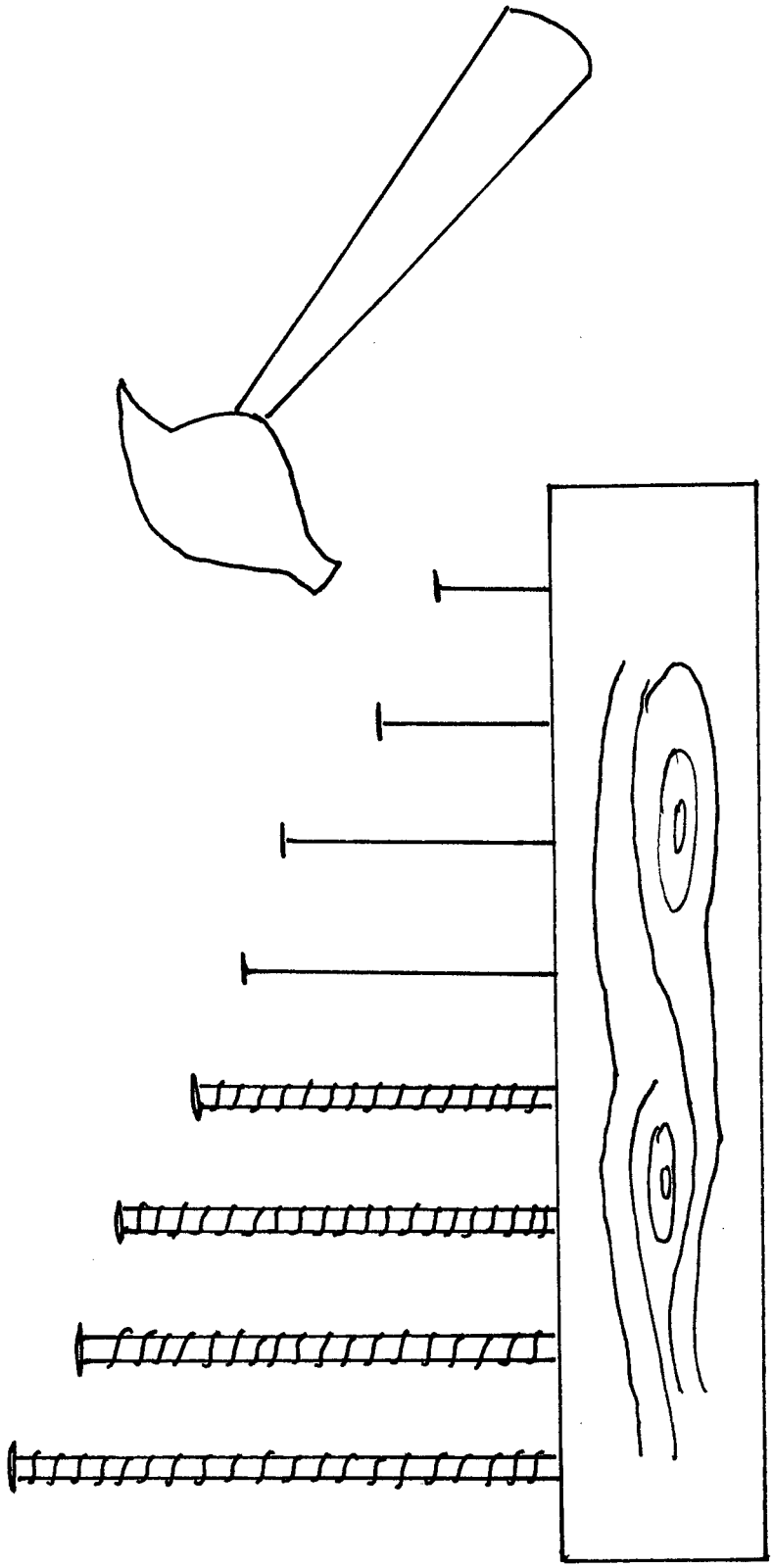

Figure 1. Nails.

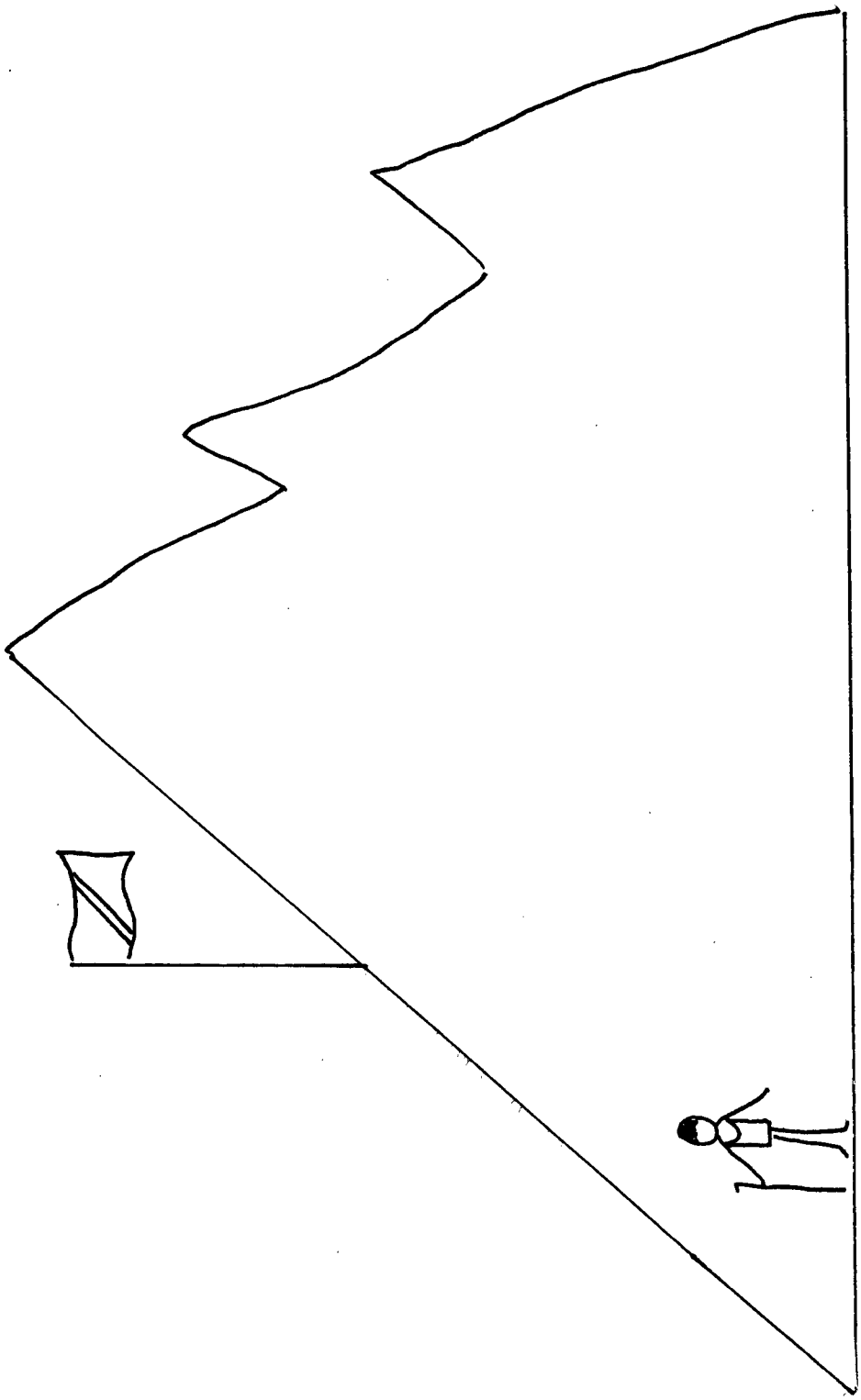

Figure 2. Flag.

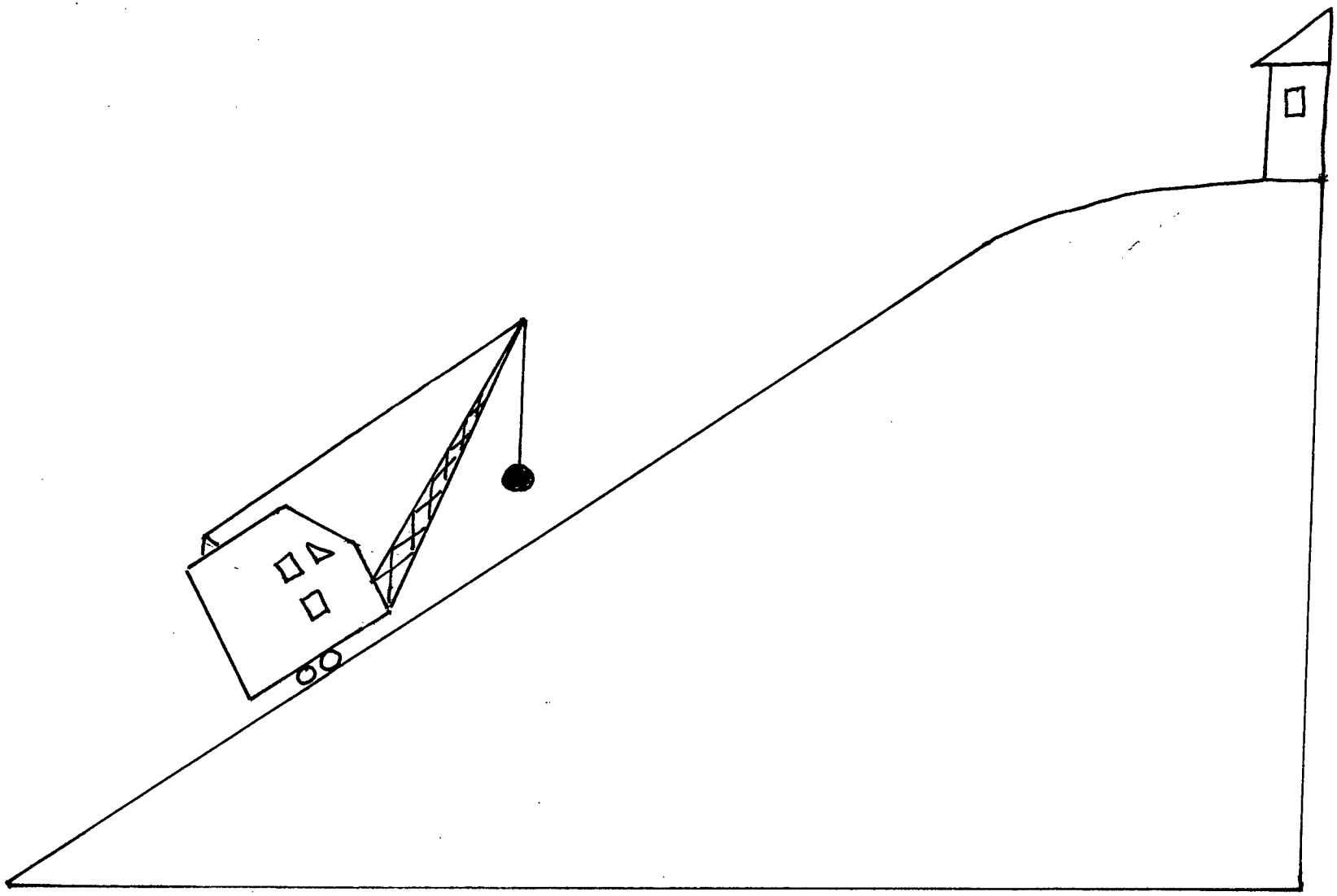

Figure 3. Crane.

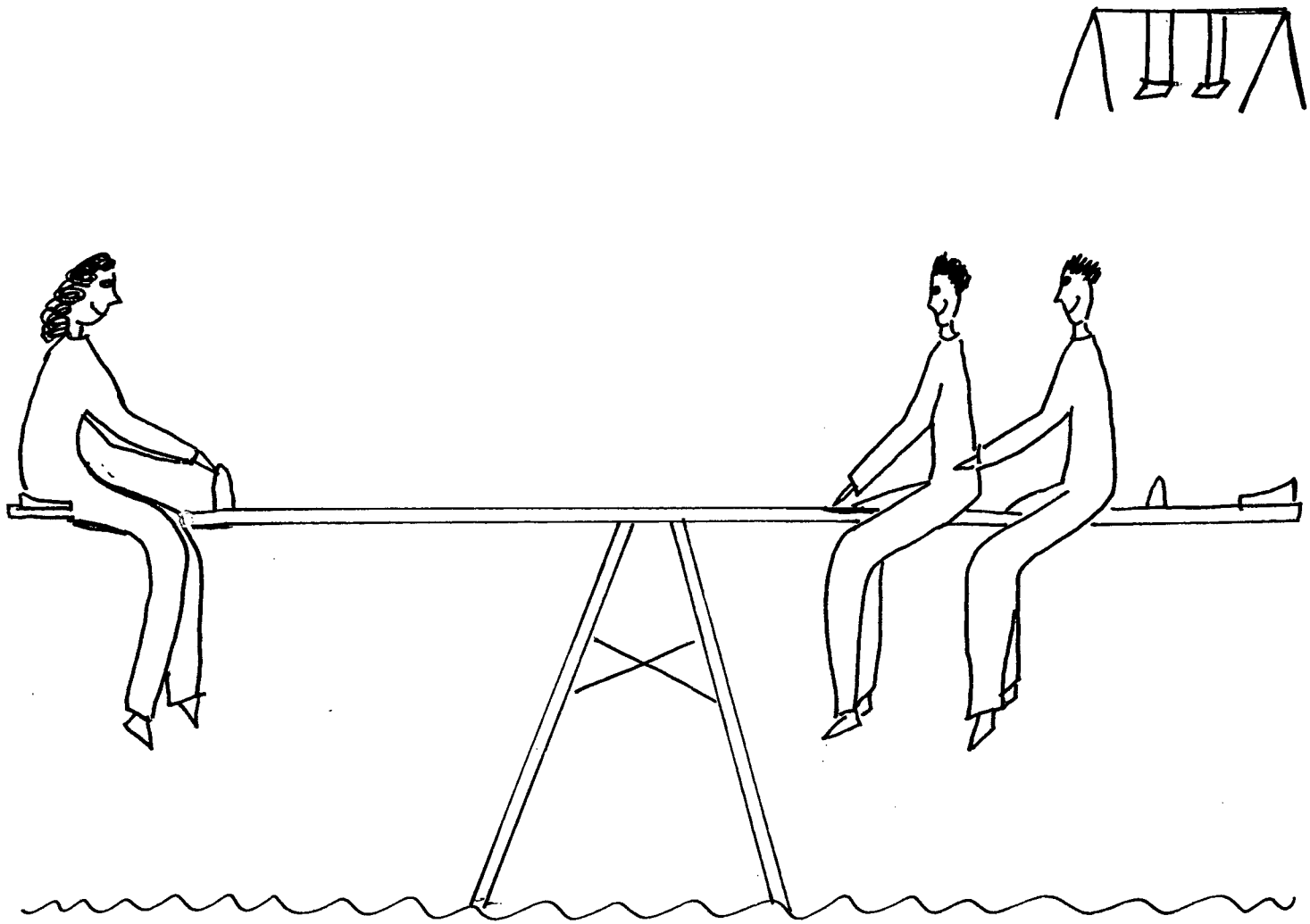

Figure 4. See-saw.

APPENDIX C

Table 1

Analysis of Variance for Verticality Assessment

Sex X Group X Time-of-Test

Source	Sum of Squares	df	Mean Squares	F	p
Sex	208.105	1	208.105	12.804	.001
Group	76.834	3	25.611	1.576	.207
Sex X Group	33.449	3	11.15	.686	.565
Error	780.168	48	16.253		
Time-of-Test	60.424	1	60.424	11.661	.001
Sex X Time	1.100	1	1.100	.212	.647
Group X Time	9.563	3	3.188	.615	.609
Sex X Group X Time	8.588	3	2.863	.552	.649
Error	248.723	48	5.182		

Table 2

Analysis of Variance for Balance Assessment

Sex X Group X Time-of-Test

Source	Sum of Squares	df	Mean Squares	F	p
Sex	34.624	1	34.624	6.745	.012
Group	10.436	3	3.479	.678	.570
Sex X Group	38.252	3	12.751	2.484	.072
Error	246.410	48	5.134		
Time-of-Test	58.335	1	58.335	27.733	.001
Sex X Time	.677	1	.677	.322	.573
Group X Time	3.947	3	1.316	.626	.602
Sex X Group X Time	.947	3	.316	.15	.929
Error	100.965	48	2.103		

Table 3

Analysis of Variance for T1

(Immediate, Day, Week, Two Months)

Operative Recognition Performance

Sex X Group X Memory Stimulus

Source	Sum of Squares	df	Mean Square	F	p
Sex	.628	1	.628	1.312	.258
Group	4.410	3	1.470	3.071	.036
Sex X Group	.018	3	.006	.012	.998
Error	22.973	48	.479		
Memory Stimulus	30.357	3	10.119	21.220	.001
Sex X Stimulus	.451	3	.150	.315	.815
Group X Stimulus	7.749	9	.861	1.806	.072
Sex X Group X Stimulus	1.891	9	.210	.441	.911
Error	68.667	144	.477		

Table 4

Overall Analysis of Variance for Initial (T1) and Two Months (T2)

Operative Recognition Performance

Group X Time-of-Test X Memory Stimulus

Source	Sum of Squares	df	Mean Square	F	p
Group	1.377	2	.689	1.180	.318
Error	22.183	38	.584		
Time-of-Test	3.258	1	3.258	18.006	.001
Group X Time	.257	2	.128	.709	.498
Error	6.876	38	.181		
Memory Stimulus	42.749	3	14.250	24.47	.001
Group X Stimulus	5.323	6	.887	1.523	.177
Error	66.387	114	.582		
Time X Stimulus	4.875	3	1.625	4.403	.006
Group X Time X Stimulus	.939	6	.157	.424	.862
Error	42.075	114	.369		

Table 5

Analysis of Variance for T2 (Two Month)

Operative Recognition Performance

Sex X Group X Memory Stimulus

Source	Sum of Squares	df	Mean Squares	F	p
Sex	2.333	1	2.333	6.468	.014
Group	.671	3	.224	.620	.606
Sex X Group	.714	3	.238	.660	.581
Error	17.317	48	.361		
Memory Stimulus	30.68	3	10.227	19.214	.001
Sex X Stimulus	1.907	3	.637	1.194	.314
Group X Stimulus	5.232	9	.581	1.092	.372
Sex X Group X Stimulus	5.581	9	.620	1.165	.322
Error	76.642	144	.532		

Table 6

Oneway Analysis of Variance Tests for Initial (T1)

Operative Reproductions from Nails, Flag, Crane, and See-saw

Source	Sum of Squares	df	Mean Squares	F	p
Nails:					
Groups	8.4029	3	2.801	4.214	.01
Error	31.9047	48	.6647		
Flag:					
Group	.2669	3	.0890	.354	.7867
Error	10.3109	41	.2515		
Crane:					
Group	.0633	3	.0211	.178	.9104
Error	4.7322	40	.1183		
See-saw					
Group	5.8297	3	1.9432	2.800	.0507
Error	31.2316	45	.694		

Table 7

Overall Analysis of Variance for

T1 (Initial) and T2 (Two Month) Operative Reproductions

Group X Time-of-Test X Memory Stimulus

Source	Sum of Squares	df	Mean Square	F	p
Group	3.002	2	1.501	1.953	.168
Error	15.373	20	.769		
Time-of-Test	1.086	1	1.086	3.71	.068
Group X Time	.823	2	.411	1.405	.269
Error	5.857	20	.293		
Memory Stimulus	17.949	3	5.983	12.389	.001
Group X Stimulus	7.042	6	1.174	2.43	.036
Error	28.976	60	.483		
Time X Stimulus	5.839	3	1.946	10.867	.001
Group X Time X Stimulus	1.833	6	.306	1.706	.135
Error	10.746	60	.179		

Table 8

Oneway Analysis of Variance Test for T2 (Two Month)

Operative Reproduction of Nails, Flag, Crane, and See-Saw

Source	Sum of Squares	df	Mean Squares	F	p
Nails:					
Group	9.1078	3	3.0359	5.072	.0038
Error	30.5286	51	.5986		
Flag:					
Group	.4787	3	.1596	.608	.6138
Error	10.7657	41	.2626		
Crane:					
Group	.3821	3	.1274	.967	.4172
Error	5.5309	42	.1317		
See-saw:					
Group	1.3715	3	.4572	1.642	.1927
Error	12.8085	46	.2784		

Table 9

Analysis of Variance for T1 (Initial)

Figurative Memory Results

Group X Memory Stimulus

Source	Sum of Squares	df	Mean Squares	F	p
Group	66.486	3	22.828	17.772	.001
Error	66.795	52	1.285		
Memory Stimulus	1.884	3	.628	.894	.446
Group X Stimulus	8.406	9	.934	1.329	.226
Error	109.617	156	.703		

Table 10

Overall Analysis of Variance for Initial (T1) and Two Month (T2) Figurative Memory Results

Group X Memory Stimulus X Time-of-Test

Source	Sum of Squares	df	Mean Squares	F	p
Group	37.17	2	18.585	9.258	.001
Error	76.281	38	2.007		
Time-of-Test	1.691	1	1.691	2.246	.142
Group X Time	10.347	2	5.173	6.872	.003
Error	28.609	38	.753		
Memory Stimulus	2.194	3	.731	.794	.500
Group X Memory Stimulus	3.993	6	.666	.723	.632
Error	104.975	114	.921		
Time X Memory Stimulus	2.764	3	.921	1.271	.288
Group X Time X Stimulus	4.882	6	.814	1.122	.354
Error	82.676	114	.725		

Table 11

Analysis of Variance for T2 (Two Month)

Figurative Memory Results

Group X Memory Stimulus

Source	Sum of Squares	df	Mean Squares	F	p
Group	20.075	3	6.692	5.249	.003
Error	66.296	52	1.275		
Memory Stimulus	6.601	3	2.200	2.375	.072
Group X Stimulus	3.333	9	.370	.400	.934
Error	144.50	156	.926		

Table 12

Analysis of Variance for T1 (Initial) Figurative Memory Results: Relevant versus Irrelevant Group X Figurative Score

Source	Sum of Squares	df	Mean Squares	F	p
Group	86.689	2	43.345	15.629	.001
Error	105.389	38	2.773		
Figurative score	9.097	1	9.097	4.971	.032
Group X Figurative score	5.715	2	2.858	1.562	.223
Error	69.532	38	1.83		

Table 13

Analysis of Variance for T2 (Two Month) Figurative Memory Results: Relevant versus Irrelevant Group X Figurative Score

Source	Sum of Squares	df	Mean Squares	F	p
Group	40.149	3	13.383	5.249	.003
Error	132.591	52	2.550		
Figurative score	13.746	1	13.746	6.722	.012
Group X Figurative score	3.812	3	1.271	.621	.604
Error	106.329	52	2.045		