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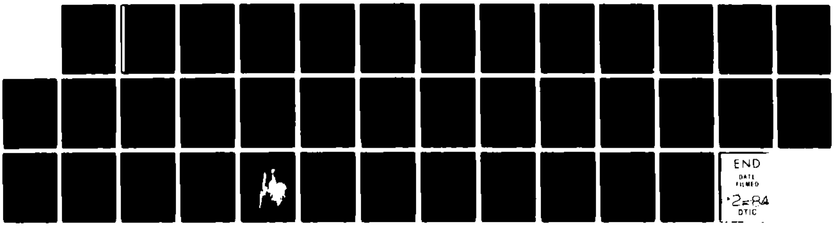

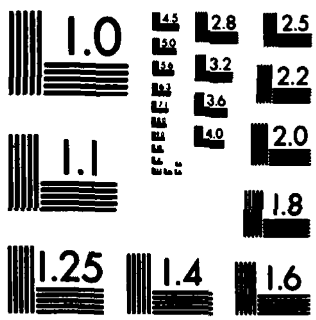
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Learning a Procedure from Multimedia Instructions: The Effects of Film and Practice

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Learning a procedure; multimedia instructions; audiovisual instructions; hands-on practice; retaining a procedure; assembly; multimedia concept formation; motoric, visual, and verbal values for locations in concepts; default value; transferring values; concept integration.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

College students were taught to build a model helicopter from an assembly kit. Their instructions consisted of a narrated film (one viewing or two), hands-on practice using a model as a guide (one building or two), or a combination (see film first, build second; or build first, see film second). Performance on assembly from memory was assessed either immediately or after a one-week delay. Both structural and functional measures were used. (A new structural measure is introduced here.) Performance was best immediately for → over

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groups who had hands-on practice, either twice, or in conjunction with a film. After a week, the group who practiced first and saw the film second performed significantly better than all others. A theoretical framework, based on multimedia concept formation, is given to account for the results. In order for lasting concepts to be formed in memory, a precedence is suggested: motoric elements should be put in first, followed by visual, followed by linguistic.

Learning a Procedure from Multimedia Instructions:
The Effects of Film and Practice

Abstract

College students were taught to build a model helicopter from an assembly kit. Their instructions consisted of a narrated film (one viewing or two), hands-on practice using a model as a guide (one building or two), or a combination (see film first, build second; or build first, see film second). Performance on assembly from memory was assessed either immediately or after a one-week delay. Both structural and functional measures were used. (A new structural measure is introduced here.) Performance was best immediately for groups who had hands-on practice, either twice, or in conjunction with a film. After a week, the group who practiced first and saw the film second performed significantly better than all others. A theoretical framework, based on multimedia concept formation, is given to account for the results. In order for lasting concepts to be formed in memory, a precedence is suggested: motoric elements should be put in first, followed by visual, followed by linguistic.

Learning a Procedure from Multimedia Instructions: The Effects of Film and Practice

In this study we tried to teach people to perform the task of building a fairly complicated object from a kit of pieces. The object to be built was a model helicopter made from the Fischer Technik 50 assembly kit. We varied the type of instruction people were given, that is, the stimulus materials that went into the instruction. Some people were taught by viewing a narrated film (either one viewing or two). Others were taught by hands-on practice (building, either once or twice, using a physical model as a guide). And others were taught by mixtures of film and hands-on practice.

The purpose of the experiment was to measure performance as a function of the multimedia instructions given. By multimedia instructions we mean instructions such as film, written text, and hands-on practice. Multimedia stimuli can be roughly divided into visual, verbal/auditory, verbal/written, and motoric (actual practice). This classification is not complete, and usually the actual stimulus material contains more than one element. For example, during actual practice, if the person is not blindfolded, a visual stimulus is present.

Other researchers have studied related questions using multimedia instructions and procedural tasks. One popular paradigm used, for example, by Margolius and Sheffield (1963), Gropper (1968), and Robbins (1983), is to vary the amount of film or video shown before a person is allowed to practice, to see if there is an optimal "work unit" size. Stone and Glock (1981) gave people written instructions, with and without pictures, and examined different kinds of errors people made. Stone, Fortune, and Hutson (Note 2) allowed subjects to request information from different modalities to see if there was a preference. But no study has tried to answer the questions posed here, and no study has examined groups similar to the ones tested here.

There is always a question in procedural tasks about how to test performance. It could be measured using many different media. For example, a person, after trying to go through the procedure from memory, could be asked to explain what he or she did. Or the person could be asked to explain what he or she would do. Or a person could go through the procedure from memory, and his or her performance could be assessed. Or the person could look at an incorrectly built object and spot and perhaps correct the errors.

The performance we tested was building from memory, either immediately after receiving the instructions, or after a one-week delay. The reason we chose this measure is that it is a direct assessment of a person's ability to execute a procedure from memory. Further, we present here a new, objective, quantitative method for scoring the finished product which assesses how similar in structure an object built from memory is to the original object, and which is relatively easy (see below). Since 360 subjects were run, ease of scoring was an important consideration.

As the results showed, there is a large variety in people's performances. Using a conceptual framework (Baggett and Ehrenfeucht, Note 1), we will attempt (see below) to explain the different cognitive processes occurring as a function of the instructions presented.

Here we give an intuitive and graphical presentation of the framework, without giving any formal definitions. Mathematical details are given in Baggett and Ehrenfeucht, Note 1.

The theoretical framework deals with concept formation, and with encoding, retaining, and using information from multimedia stimuli. As mentioned above, such stimuli include not only spoken or written verbal elements, but also, importantly, nonverbal elements, including still pictures, moving pictures, and actions.

The framework uses integrated concepts. That is, each concept contains elements from different media, which correspond to words, pictures, actions, etc. These multimedia concepts have a hierarchical structure. That is, concepts can have subconcepts, which can have subsubconcepts, and so on.

Within the framework there is a single conceptual memory. (Many other researchers also assume a single conceptual memory, for example, Anderson and Bower, 1973; Collins and Loftis, 1975; and Norman and Rumelhart, 1975.) The memory is connected to multiple processors. Processors can be thought of as processing visual input, auditory input, tactile input, and so on. Processors take input signals and put them into memory, forming concepts.

Concepts are not independent. If processor A builds a concept, then processor B can build another concept that is a part of it. This gives the hierarchical structure and the multimedia aspect: Visual, auditory, and motoric information, for example, can be part of the same concept.

Processing of concepts is done uniformly, independent of the media that went into their formation. The action of a processor is governed by a concept already in memory. A concept which governs what a processor does is called a concept which is executed by the processor.

Besides interacting with memory, processors interact with the environment. For example, the motoric processor can cause an action to occur.

Hypotheses regarding what memory is, how concepts are located and linked in memory, and how concepts are formed and modified, are formulated in Baggett and Ehrenfeucht, Note 1.

The theoretical approach has been briefly sketched. The concern here is to match the approach with experimental data. We make one important point before doing so.

We assume there is a distinction between having a slot or location for information in a concept and filling the slot with specific information, that is, giving it a value. Here we give an informal example of this distinction.

Suppose the stimulus is, "Chop up a red pepper." The input is verbal. The concept created has a verbal component consisting of a location with the value, "Chop up a red pepper." Its visual component consists of a location for color and a location for recognition of the object. (The values for these locations are not defined by the input.) The motoric component consists of a location for the action to be performed. (Again, the value for the motoric location is not defined by the input.)

Let us now change the stimulus from the sentence, "Chop up a red pepper," to one that is visual. Suppose the action of chopping up a red pepper is shown via a (silent) movie. A concept similar in structure to the one above is created. But the verbal component has a location whose value is not defined by the stimulus. And the visual component has locations for color and object recognition whose values are defined by the stimulus. The motoric component consists of location for the action to be performed, but its value is not defined by the input.

One extra mechanism can be postulated here, namely, the notion of a default value for a location. (See Minsky, 1975.) For example, with the verbal stimulus "red," one makes a concept with a visual slot that can be filled with a value, and the value for the visual slot can be filled from memory, based on the typical red which one has seen previously. If such a mechanism is operating, then showing red to a person later on can be unnecessary. But it can also lead to an error: the exact red shown later may not be encoded (assigned as the value), because the default value has taken precedence.

The questions that relate experimental data to the framework deal with the concepts that are formed depending on the stimulus materials presented during instructions (audiovisual and hands-on practice). We assume that hands-on practice causes motoric, visual, and verbal locations to be formed, with motoric and visual values defined by the stimulus. Narrated film instruction causes motoric, visual and verbal locations to be formed, with visual and verbal values defined by the stimulus.

Suppose practice and film are presented in some order, for example, practice first or film first. What processing goes on? We assume the subject creates one concept for the first instruction, and a second for the second instruction. Our interest was in the following questions:

1) Can a person transfer values from one concept to another concept? How does transfer occur as a function of the order of stimulus presentation?
2) Can a person create one concept from two presentations? Namely, can the person identify one concept with another, so that they become one?

The difference between transferring values and integrating concepts can be hard to distinguish. We assume that, when tested immediately after receiving instructions (at zero delay), a subject can use different concepts, simply because they have been formed recently. The subject can create a composite concept which allows him or her to solve the problem at test time. After a delay, we expect that only one concept is used by a subject. Therefore, a lack of integration will show up as a difference between performance at zero delay and performance after a one-week delay.

In this study, the main question concerned the transfer of values between motoric and visual elements obtained during practice, and visual and verbal elements obtained from a narrated film. We measured how performance depends on the mixture and importantly, the order of the stimulus materials. In the discussion, we present the hypothetical interpretation that explains the results, and an interpretation of when concepts were formed and what they contained. We also can specify for which instructional sequences the transfer of information from one concept to another is carried out efficiently.

Method

Subjects

Three hundred sixty students in Introductory Psychology at the University of Colorado participated as part of a course requirement. The students were divided into 12 groups, with 15 males and 15 females per group. Subjects were randomly assigned to their groups. Six of the groups were given the following instructions, with subjects tested immediately afterwards: group one: first see film, then build from model; group two: first build from model, then see film; group three, see film twice; group four, build from model twice; group 5, see film once; group 6, build from model once. The other six groups were given the same instructions, with subjects tested one week later. The test for all groups was to build the model helicopter from memory.

Design

The experiment was a 6x2x2 between-subjects design. There were six types of instruction (1. first see film, then build from model; 2. first build from model, then see film; 3. see film twice; 4. build from model twice; 5. see film once; and 6. build from model once), and two delays (0- and 7-day). Further, half the subjects in each group were male and half female.

Stimulus Materials

The assembly kit, Fischer Technik 50, is similar to Lego. Manufactured in Germany, the kit has 120 total and 48 different plastic, metal, and rubber pieces. The smallest piece is $5mm^2$ ($.2\ in^2$) and the largest is 90 x 45 mm (3.54 in x 1.77 in). The manufacturers recommend its use by children as young as six through adults.

The object to be built, a model helicopter, consists of 54 total and 24 different pieces. It is shown in Figure 1.

Insert Figure 1 about here

The instructional film, a 15 min color presentation, was shot and edited by a professional film maker, James Otis, using super 8 film. It was narrated by the author. The narration consisted of 856 words. The film presented the helicopter as consisting of seven subassemblies. (In a different study these units were shown to be the same as those of the majority of people who built the helicopter using a physical model as a guide. They can thus be considered to be natural units. Details of the method for determining these units are in Baggett, in press a.) Names to be used in the narration for the 24 different pieces were selected using a method described by Baggett and Ehrenfeucht (1982). The names are simple, short, easily matched with their physical referents, and fairly well recalled. Names to be used in the narration for the seven subassemblies of the helicopter (propeller assembly, seat, upper body, lower body, tail assembly, main gear, and wheel and gear assembly) were derived in a pilot experiment. In the experiment, subjects were given the helicopter broken into the seven subassemblies. They were required to build one like it, with the constraint that each of the subassemblies be built individually. After building, each person named each subassembly. Using the method in Baggett and Ehrenfeucht (1982), the most commonly generated name for each was chosen and used in the film's narration. The first few sentences of narration are given in the Appendix. The script is available from the author.

<u>Procedure</u>

Instructions were presented to individual subjects, or to small groups of two or three. Subjects first filled out questionnaires indicating whether they had played with the Fischer Technik kit or with Lego, Erector sets, or similar kits, before. They rated how much they had played with the kits on the following scale: 0 (never); 1 (once or twice); 2 (fairly frequently); and 3 (lots). They were then given the following instructions: "Today we are going to give you some instructions on how to build a fairly complicated object from this kit of pieces. After the instructions (and at the appropriate delay, either zero or one week) you will be asked to build the object from memory, so try to learn as much as you can from the instructions."

They were then told that, to familiarize themselves with the kit's 48 different pieces, they would first do a matching task. Each person was given a box containing one of each of the 48 different pieces in the kit and four sheets of paper with 48 names, 12 names per page. They were instructed to place each piece by its correct name. They were told that the task was not a test, and that they could ask the experimenter at any time what the name of a piece was. Subjects finished this task in five to ten minutes, and experimenters then checked and corrected their errors, pointing out the corrections. The pieces and their names were then removed.

Subjects were then told what their instructions would consist of (one or two films, building from a model once or twice, building from a model once and then seeing a film, or seeing a film and then building from a model).

Procedure for Showing the Film

The film was projected on a 38" x 28.5" (96cm x 72cm) screen such that the visual image filled the screen. Subjects were told this and allowed to adjust their chairs before the film began, centering them before the screen at any distance they chose. The film was shown in a completely dark room. For the groups who saw the film twice, the break between showings was just long enough to rewind the film and thread it again into the projector.

Procedure for Building from a Physical Model

Each subject was run by an individual experimenter in this phase. A physical model was placed before each subject. The subject was allowed to pick up and examine the model at any time and could disassemble parts of it if necessary. In building his or her copy of the model, the subject was required to ask for each piece, either by name or by pointing. At the subject's side was a collection of each of the 48 different pieces in the kit and also a folder with color photos and names of each of the pieces. These could be used by the subject as he or she requested each piece. The experimenter had a data sheet on which each of the pieces of the helicopter was laid out and numbered. The experimenter handed the subject each piece requested, and recorded the order of request on the data sheet, as the subject worked. In this way, the experimenter could check that the subject built a perfect model. (All subjects did so.)

For the groups who built the model twice, the break between the two was just long enough for the experimenter to disassemble the subject's first model and place the pieces back in the kit.

Subjects in the immediate test conditions began their memory trials as soon as the instructions were completed. Subjects in the one-week delay groups returned 7 days later for their memory trials.

Procedure for Memory Trial

Each subject was tested by an individual experimenter in this phase. In building from memory, subjects were required to ask for each piece they wanted to use, either by name or by pointing. A collection of the 48 different pieces in the kit and a folder with 48 color photos and names were at the subject's side (as above), to aid in this task. (All 48 different pieces were available to the subject, not just the 24 different ones occurring in the correctly built helicopter.) Subjects were told they could ask for as many different pieces, and as many pieces of one kind, as they wanted, and that they were not required to use a piece once they had asked for it. They were also told that they could make as many changes as they wanted while they built. They were limited to one hour for the memory trial.

Results

For convenience, we introduce the following abbreviations for the six groups: FM = see film first, build from model second; MF = build from model first, see film second; FF = see film twice; MM = build from model twice; F = see film once; M = build from model once. The FM groups tested at zero delay and 7-day delay will be abbreviated FM-0 and FM-7 respectively, and other zero- and 7-day delay groups will be designated similarly.

In building the helicopter from memory, only 4.7% (17 of 360 subjects) constructed a perfect model (two from FM-0; six from MF-0; three from FF-0; and six from MM-0). The degree of correctness of assembly was measured by two specific criteria, one structural and the other functional.

The structural criterion measures how much the helicopter built from memory differs from the correctly built helicopter. There are many possible structural measures. For example, which connections were made incorrectly? Were some pieces replaced by others, with possibly the same functional result?

In our experiment, we used a new quantitative structural measure which to our knowledge has not been used before: <u>number of correct connections</u>.

Each subject's helicopter built from memory was drawn as an abstract graph whose nodes represent pieces and whose links represent physical connections. (As an example, Figure 2 shows the abstract graph of the correctly built helicopter pictured in Figure 1. Nodes in Figure 2 are numbered 1 through 54, to correspond to specific pieces in the helicopter.)

Insert Figure 2 about here

Each subject's graph was compared to the graph in Figure 2, and correct connections in the subject's helicopter were counted. For example, is piece 1 connected to piece 2? 2 to 3? 3 to 4? 3 to 7? (At least two experimenters scored every helicopter. When there was disagreement about the presence of a connection, a third experimenter scored the helicopter independently and broke the tie.) The correctly built helicopter contains 58 connections (which can be seen in Figure 2). Scores on the helicopter built from memory could, therefore, vary from zero to 58.

Table 1 presents the average percentage of correct connections for each of

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Insert Table 1 about here

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the 12 groups (and the percentage functional, to be explained below). The 6x2x2 (instructions x delay x sex) between groups ANOVA on the structural scores yielded a significant main effect of instructions, $F(5,336) = 3.10$, $p < .01$ (MS(error) = 125.4); a significant main effect of delay, $F(1,336) = 252.3$, $p < .01$; and a significant main effect of sex, $F(1,336) = 55.1$, $p < .01$. The interaction of instructions x delay was significant, $F(5,336) = 3.57$, $p < .01$. The other three interactions (instructions x sex, delay x sex, and instructions x delay x sex) were not statistically significant ($F < 1$, $F < 1$, and $F(5,336) = 1.28$, respectively).

The average percentages of correct connections in the six groups (FM, MF, FF, MM, F, and M), collapsed over delay, were 60.7, 66.4, 50.4, 63.3, 28.25, and 53.65 respectively. The average structural score at zero delay was 59.95%; after a week, it was 37.62%. (The ratio of the two, a measure of retention, is

53.8%.) Overall, males scored 61.34% and females 46.23%.

As mentioned above, a second criterion of assembly performance was an assessment of functionality of the model built from memory. The helicopter is operationally defined to be functional if its blades turn when it is pushed along a surface. Each model was scored as functional or nonfunctional; there was no partial credit.

The scores for functionality paralleled the structural scores. The percentages functional were 61.65, 65.0, 43.35, 55.0, 23.35, and 48.35, in the six groups, ordered as above and collapsed over delay. At zero delay, 55.02% were functional; after a week, functionality was 43.88%. (These numbers give a retention rate of 79.8%, substantially higher than the retention of structure, 53.8%. That function is retained better than structure is not surprising.) Males built 65.57% functional helicopters; 33.33% of helicopters built by females were functional. Statistical analyses were not performed on the functional scores since their pattern was very similar to the structural scores.

One Newman-Keuls procedure was performed on the structural measure to test differences between pairs of means (Winer, 1971, p. 442) at zero delay; and a separate procedure was performed to test differences at 7-day delay. (In each case, data from males and females were combined.) For both 0- and 7-day delay, MS(error) = 145.1. The critical value for a .05-level test for adjacent means, $q_{.95}(2,348)\ S_{\overline{AB}}$, is 10.5%.

Therefore, at zero delay, the six groups line up as follows based on their structural scores (see also Table 1):

$$MM = MF = FM > FF = M > F.$$

Thus, when the test immediately follows instructions, some motoric training is good: either practicing twice or practicing once combined with seeing a film. (Order of practice and film does not matter.) Second best is practicing once or seeing the film twice. This means that, at least when the test is immediate, audiovisual instruction can be substituted for some practice, if the amount of audiovisual instruction is increased. We also note the increase in performance from the F to the FF group (36.8% to 68.9%). This means that (immediate) performance resulting from audiovisual instruction for a procedure can be significantly improved when the instruction is shown twice rather than once. We do not know whether, by repeating the film (giving only audiovisual components to a concept), we could ever match the three top groups, all of which have a motoric component.

After a week delay the six groups line up statistically (using a Newman-Keuls procedure as before) as follows (once again, based on structural scores; see also Table 1):

$$MF > MM = FM = M = FF > F.$$

As shown in Table 1, all groups are depressed to about 1/2 of their zero-delay scores. But there is one group that stands out above the rest: MF. As mentioned above, a measure of retention may be defined as the score at 7 days divided by the score at zero delay. The MF group retains 65% of what was originally encoded. Retention rates for the other five groups range from 46% to 57%.

Discussion

We give here an interpretation of the results in terms of the theoretical framework, i.e., in terms of the concepts formed. Before doing so, we review two points mentioned in the introduction. First, depending on the stimulus presented in instructions, the concept formed can have some values for locations missing. For example, seeing the film does not provide motoric values. When motoric values are not provided by the stimulus, they can be undefined or defined by default. (The person has done something similar before, so the (motoric) memory of the similar action is used as a value in the new concept.)

The second point regards whether, in the different groups, one or two concepts are built. We expect that in the groups where the same stimulus is repeated (FF or MM), one single concept is formed, and the repetition simply reinforces the concept formed during the first stimulus presentation. The repetition will yield (1) a better encoding of the stimulus presented; and (2) a better chance that the missing values can be provided by default. With one presentation, a person may not have time to search through other concepts in long term memory to find the default values needed to fill the slots. (We think that this search is similar to the reinstatement search hypothesized by Kintsch & van Dijk (1978) in their model of text comprehension.)

For the groups who receive both film and practice, we expect that, even if two separate concepts are formed, they can be used by subjects at zero delay to perform the task, simply because the concepts have been encoded close together temporally. A person can form associations between the two at zero delay, and use them both to solve the problem. We also expect that, when the task is performed after a week delay, only one of the concepts formed will be used. That is, the chance that the two concepts are integrated is far smaller. As we mentioned in the introduction, we hypothesize that the difference between one integrated and two separate concepts can be detected based on performance with and without a delay.

We also hypothesize as follows regarding <u>when</u> one can create default values for locations for media not presented in the stimulus materials. Before default values can be created, locations for the values are required to be present in the concept.

We first line up the media as follows: motoric first; visual second; verbal third. We hypothesize that a motoric stimulus creates locations for visual (as well as motoric) values. A visual stimulus creates locations for both motoric and verbal (as well as visual) values. Finally, a verbal stimulus creates locations for visual (as well as verbal) values. That is, locations are created for the medium presented, and for the media one step on either side of the one presented, as they are lined up above. This hypothesis is illustrated in Figure 3.[1] A default value may be provided if and only if a location for a value is present.

Insert Figure 3 about here

In the experiment, we assume that practice is a motoric and visual stimulus, and a narrated film is a visual and verbal stimulus. Each (practice and film) can create locations for all three media (motoric, visual, and verbal), but each does so more or less strongly. For example, practice creates locations (and possibly default values) for verbal material, but the values, if they are defined, are more imperfect than if the verbal material were actually presented.

With the above theoretical background, we can interpret the experimental results. We first note that the task the subjects performed (building from memory) is highly biased toward a motoric and visual stimulus. To perform the task, a subject must have an executable concept that is motoric and visual; the subject is not tested on any verbal measure.

At zero delay, the groups line up as follows: MM = MF = FM > FF = M > F.

For the three top groups, we do not know whether subjects formed one or two concepts. (We hypothesize about this only on performance after a delay.) But clearly, a repeated motoric element dominates, and the MF and FM groups perform equally well (see Table 1). The MM group is missing some of the visual and verbal elements provided by the film, but with two practices, default values seem to be good enough.

The FF and M groups are tied for second at zero delay. We assume that the concepts formed in the two groups are similar. Thus some default values must be provided in each case.

The F group is poorest. Getting motoric values from the film is difficult. (see Footnote 1.)

After a week delay, the groups line up as follows: MF > MM = FM = M = FF > F.

The F group is still poorest. The FF and M groups remain together, with a change of order from their zero delay ranking. (FF is slightly but not significantly worse.) We note that the film contains linguistic elements, which are lost after a week (Baggett & Ehrenfeucht, 1983). This loss may cause a greater deterioration in performance for FF.

The performance of the MM group is not statistically different from that of the M group after a week (although they were significantly different at zero delay). This means that the decay of the reinforced concept (MM) occurs at a faster rate than the decay of the same unreinforced concept (M).

Performance of the FM group after a week is statistically the same as that of the M group and significantly worse than the MF group. This is theoretically interesting. We think that the FM group created two separate concepts. The first has audiovisual components with undefined values that are motoric. The second has visual and motoric components with undefined verbal values. The values from the second do not seem to be transferred to the first; the two concepts do not become integrated. Possibly in practicing second, the subject has the motoric elements needed for the task and is not motivated to look back to the undefined values in his or her audiovisual concept. The subject has everything needed, namely, the subject has just successfully built the helicopter.

We hypothesize that, in building from memory, subjects in the FM group used only one of their concepts, the one formed from building from the model (containing visual and motoric elements). Thus, their performance equals that of the M group.

The MF group performed best (and significantly so) after a delay. We hypothesize that they created a single unified concept from their stimulus presentations. In building first from a model, they built motoric components with defined values. In watching the film, they formed an audiovisual concept with undefined motoric values. The subjects seemed to connect the two: audiovisual back to motoric; they filled the slots in the audiovisual concept with their practiced motoric values, forming one integrated concept. The concept contained all elements (motoric, visual, and verbal), and a subject simply executed it in performing the task.

Our main result is the superior performance of the MF group after a week. We propose, based on this result, that elements in people's concepts form a precedence: primary is motoric, second is visual, and third is language (symbolic information). To form lasting concepts, the order in which the multimedia information enters a concept seems important. From this experiment, motoric information should enter first, and audiovisual second.

In another study (Baggett, in press, b) the soundtrack of a film was shifted, so that an object shown in the visual image and its corresponding verbal label could be in synchrony or the visual image could precede or follow the spoken label. The best recall of a name, given the object, was for the groups with visuals and verbals in synchrony and with visuals preceding verbals by up to seven seconds. The principle arising from that study was that for good visual/verbal associations to be made, one should show and tell in synchrony, or show first and tell second, and one should not tell first and show second. (A similar result was obtained by Baggett & Ehrenfeucht, 1983.) Thus, in the framework given here, visual elements should arrive at a concept ahead of, or in synchrony with, their verbal labels, in order for integrated concepts to be formed.

The theoretical explanation given here is ad hoc. But the fact that it is consistent with previous results gives it credibility. We think that it is a viable hypothesis that we can expect to find in a broad range of cognitive research.

We note that the correlations between structural scores and ratings given on the questionnaire about how much one had played previously with assembly kits (on a scale of zero to three) were positive in all 24 (6x2x2) cases. The correlations ranged from .05 to .60 and averaged .28. The correlations mean that previous experience on similar tasks and performance on the task performed here are related. The mean ratings of previous experience ranged from 1.30 to 1.67 in each of the twelve groups (combining males and females). It is interesting to note that the average rating for females is 1.31 and for males is 1.66. The ratio of these two is 78.9%, which is approximately the ratio of the structural scores for females to those for males (46.23/61.34 = 75.4%). One reasonable explanation for the sex difference in this study is simply the difference in previous experience on similar tasks.

The experimental results found in this study do not allow us to recommend a general principle for multimedia training of a procedure. Individual differences in performance within a group were very great. For example, scores could range from 0 to 58, and an actual range in a single group of 2 to 56 was common. The average standard deviation in a group was over 20%.

We conclude that the right training sequence for a procedure that is to be performed from memory varies, depending on the individual. And this brings up the question of individualized instruction. A goal of our future research is to discover what individualized instruction should contain. Specifically, should instruction be individualized simply by varying the amount given to different people, depending on their experience or skill? Or should it be individualized by giving different modalities, or modalities in different orders, or different conceptualizations (divisions into subassemblies), etc? A second goal of our future work is to develop a small number of brief tests that can be easily given to subjects. Performance on these tests would be used to (a) predict performance as a function of instructions; and (b) assign a person to an appropriate instructional sequence.

Until such tests are available, we recommend that a person's performance be tested after practice, after film instruction, and after various amounts and combinations, to see which gives optimum results. If such testing is not possible, the instructional sequence should be practice first and film second.

Final Remarks

This paper has investigated performance on an assembly task as a function of the multimedia instructions given. It has put forth a new dependent measure for assembly which assesses the similarity in structure of an object built from memory and a correctly built object. It has also sketched a theoretical framework based on multimedia concept formation which is helpful in interpreting the empirical findings. We hope that the new methodology, the framework, and the practical results will be useful in a variety of situations.

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Footnotes

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[1]In actuality, we think the situation is slightly different. First, a stimulus in one modality creates a location (with some probability) for the *next lower* modality (motoric creates a visual location; visual creates a verbal location; see Figure 3.) Location creation proceeds easily in the downward direction. Suppose a motoric stimulus creates a visual location. If the visual location is given a value by default, this *causes a verbal location to be created*. Thus, a motoric stimulus can (indirectly) cause a location two steps away to be created.

If a visual stimulus is presented, a location is created for its verbal label. The location is not necessarily filled with a value.

Location creation in the upward direction (verbal to visual, or visual to motoric) occurs with a lower probability. It is not very likely that a verbal stimulus can cause motoric locations to be formed. One does not directly encode actions from words.

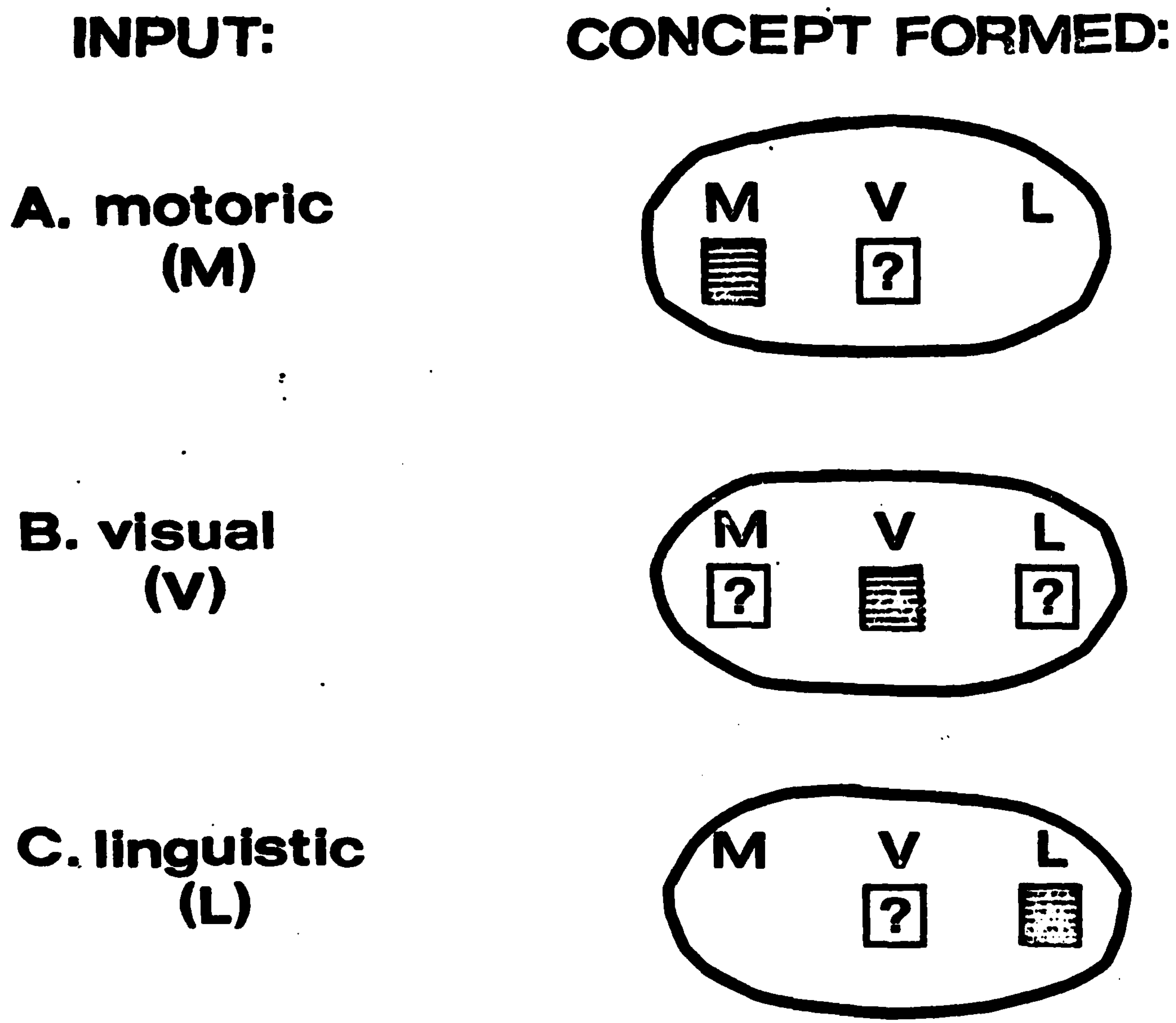
This report is technical report #125 of the Institute of Cognitive Science's technical report series.

Table 1: Percentage of Correct Connections in

Helicopter Built from Memory, and Percentage Functional, for Each of 12 Groups

	stimulus one	see film	build from model	see film	build from model	--------	----------
	stimulus two	build from model	see film	see film again	build from model again	see film	build from model
	abbreviation	FM	MF	FF	MM	F	M
groups tested at zero delay:	percentage correct connections	80.3	80.5	68.9	84.9	36.8	68.3
	percentage functional	70	60	50	66.7	26.7	56.7
groups tested at 7-day delay:	percentage correct connections	41.1	52.3	31.9	41.7	19.7	39
	percentage functional	53.3	70	36.7	43.3	20	40

Note: There were 15 males and 15 females in each of the 12 groups.


INPUT:
CONCEPT FORMED:
A. motoric
(M)
M
V
L
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B. visual
(V)
M
V
L
?
?
C. linguistic
(L)
M
V
L
?

Figure 3

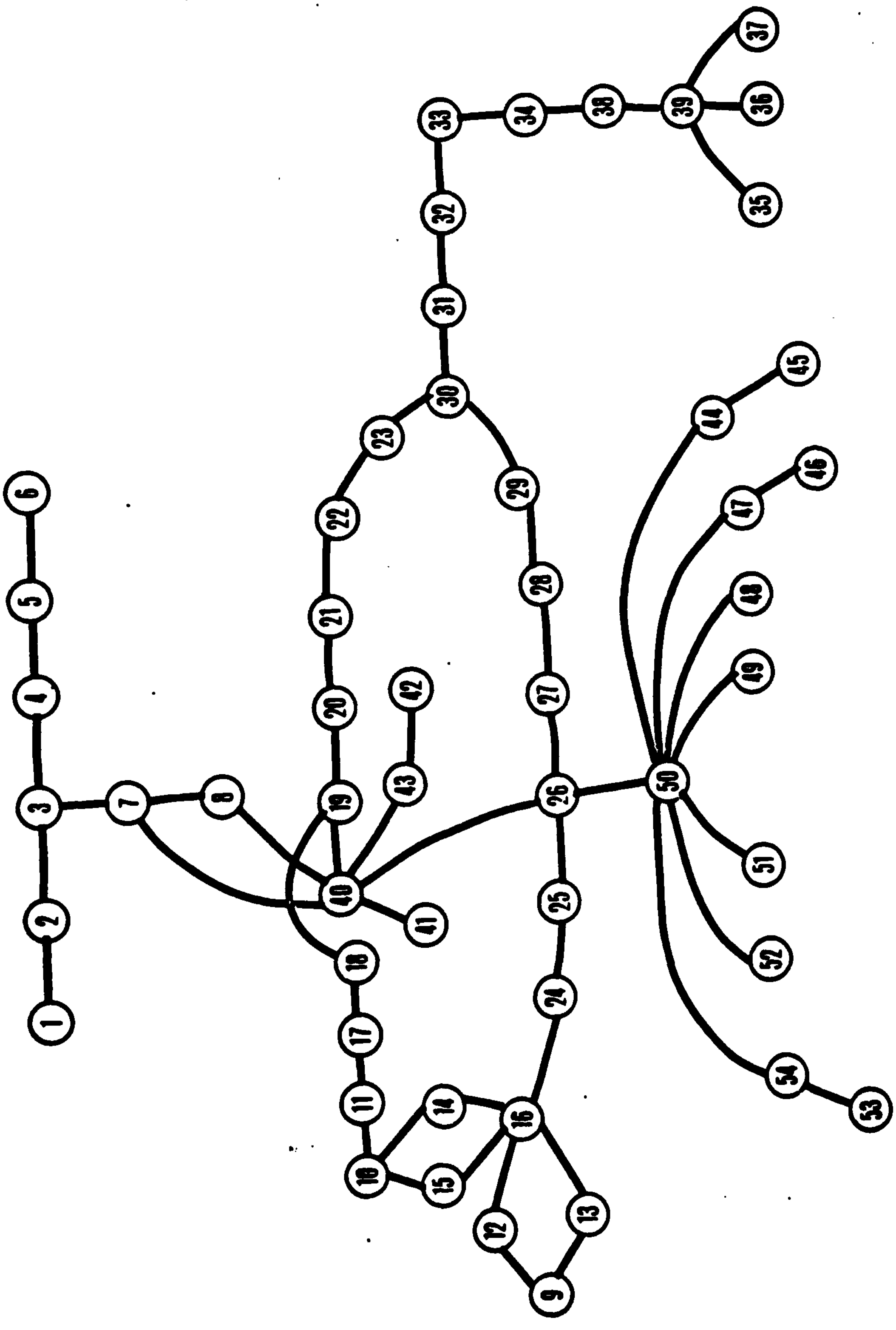
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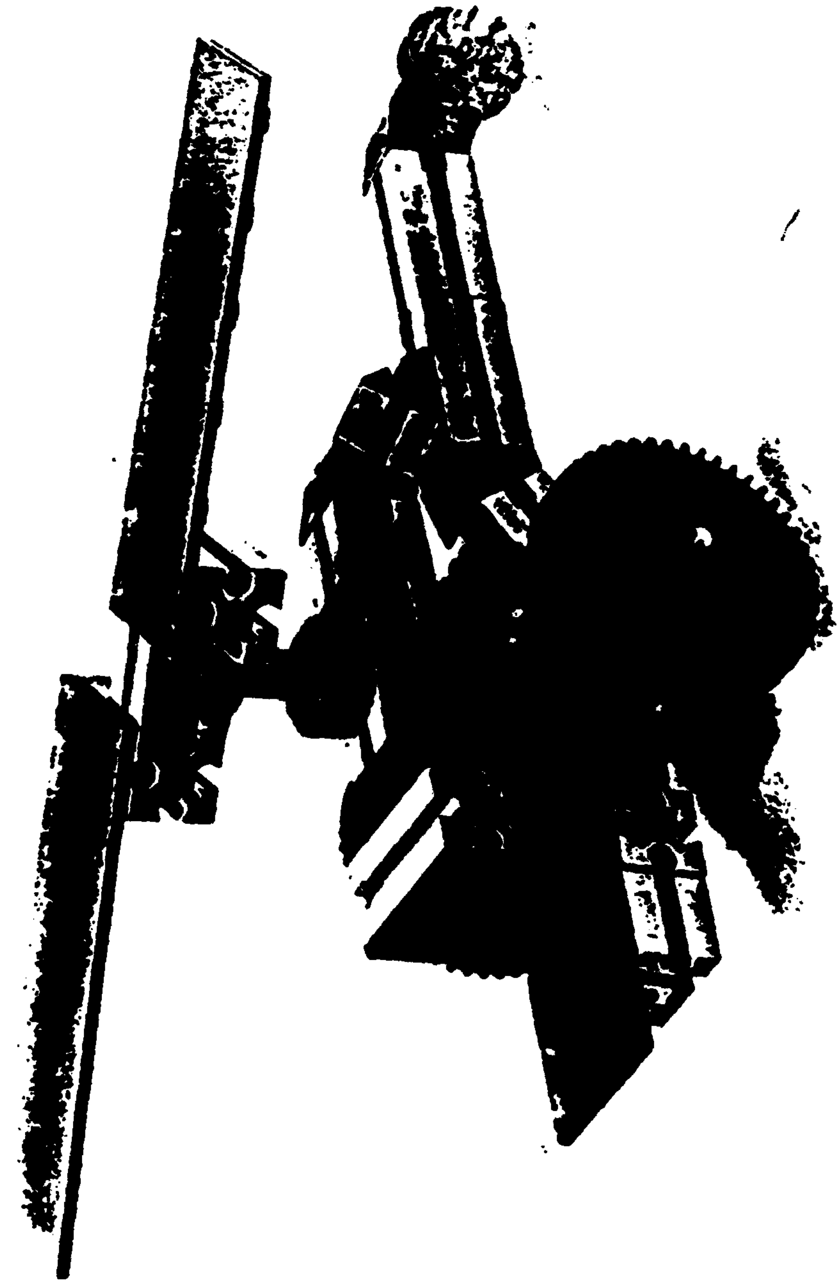
Figure 2



Figure

Figure Captions

Figure 1. The model helicopter, built from 54 pieces of the Fischer Technik 50 assembly kit.

Figure 2. An abstract graph of the model helicopter shown in Figure 1. The nodes represent pieces and the links represent physical connections. The nodes are labeled 1 to 54, to correspond to specific pieces in the model. For example, nodes 1 and 6 correspond to the blades, and nodes 45 and 53 correspond to the tires. For scoring performance, the graph of a helicopter built from memory was compared to the graph of the correctly built one (shown above), and the number of correct connections was counted.

Figure 3.

Note: Squares indicate locations. Horizontal bars indicate defined values. A question mark indicates that the value is either undefined or defined by default.

In the theoretical framework, motoric elements (A above) create concepts with defined motoric values, and with locations for visual (and possibly linguistic; see Footnote 1) elements. These locations have values that are defined by default or left undefined. Visual elements (B above) create concepts with defined visual values, and with locations for motoric and linguistic elements. These locations have values that are defined by default or left undefined. Linguistic elements (C above) create concepts with defined linguistic values, and with locations for visual elements. These locations have values that are either defined by default or left undefined. (See also Footnote 1.)

Appendix

The film contains 856 words of narration. It begins as follows:

The helicopter consists of 54 pieces from an assembly kit. As the helicopter is pushed along a surface, its two gears mesh and its blades turn. *The purpose of this film* is to show *you* step *by* step how to build the helicopter. It consists of seven sections.

The tail assembly connects to the lower body. The propeller assembly attaches to *the upper body. The C-clip* slides *on* the *rod*, *and* the *main gear* attaches to the rod. The lower body fits on the rod. . . . .

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